POWER REQUIRED FOR ELECTRIC SWITCHES AT THE CHICAGO & NORTHWESTERN RAILWAY

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1912

A DETERMINATION OF THE POWER REQUIRED FOR THE OPERATION OF THE TYPES OF ELECTRIC SWITCHES AND SIGNALS IN USE AT THE CHICAGO TERMINAL OF THE CHICAGO AND NORTHWESTERN RAILWAY.

A THESIS

PRESENTED BY

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The foremost object of this thesis is a determination of the power consumption of the signal apparatus in use at the Chicago Terminal of the Chicago and North-Western Railway. Such a power consumption may be defined in this case to mean the values of current required for the operation of the apparatus. This meaning is so chosen because the majority of cases where power supply is in question, are determined by current capacity of the source of power; and also because the signal and switch apparatus are constructed for definite voltages.

The points on the Chicago terminal selected for the necessary tests are:

(1) Canal Junction Interlocking Plant, Milwaukee Division, Evanston Illinois.

(2) Clinton Street Interlocking Plant, junction of Galena and Wisconsin Divisions, Chicago Illinois.

(3) Lake Street Interlocking Plant, Chicago Terminal Station.

(4) Signal Bridge, Central Street, Evanston Illinois.

(5) Signal Bridge, Rogers Park Station, Chicago Illinois.

(6) Section of track on Galena Division extending west from the Clinton Street Interlocking Plant.

These points were selected not only because

they represented average conditions, but also because of the possibility of obtaining the desired information with the least chance of interference with traffic;-the time of day being considered.

The types of apparatus here represented and tested are manufactured by the General Railway Signal Company, the Hall Signal Company, and the Burke Electric Company. These various types will be discussed in the order mentioned below.

(1) Model 2A, three position, high voltage signal mechanism. (General Railway Signal Co.)

(2) Model 2A, three position, low voltage signal mechanism. (General Railway Signal Co.)

(3) Signal mechanism. (Hall Signal Co.)

(4) Model 2 switch machine. (General Railway Signal Company.)

(5) Model 4 switch machine. (General Railway Signal Company.)

(6) Track circuits,- automatic,- interlocking.

(7) Motor-generator sets. (Burke Electric Co.)

MODEL 2A HIGH VOLTAGE MECHANISM.

The model 2A, three position, high voltage mechanism consists essentially of three parts. These are (a) motor, (b) circuit breaker, (c) gears, and are, with the exception of the gears, indicated upon the typical circuit shown. The motor F is a two-pole series motor. The two operating fields are indicated by DD. The other two fields EE are for retaining purposes only. That is, at the proper moment EE are connected in series with DD and the armature, thus clamping magnetically the armature in that position. This magnetic force exerted is sufficient to hold the blade of the signal in the desired position. To facilitate this retaining of the blade, the pole shoes of the field EE are slotted with slots and teeth to coincide with the armature slots and teeth.

The circuit breaker, whose elements 1-2-4-6 etc. are attached to the cylinder G, is shown with its surface developed. The various contacts shown at 1-2-4-6 etc. are adjustable copper springs arranged to rub upon brass strips attached to the surface of the cylinder. These brass strips are so located upon the cylindrical surface, that they make and break contact between the upper and lower springs at the desired moment. Additional contacts and springs 8-10-12 are provided where it is necessary to interconnect the circuit

of one signal with one or more signals or switches.

The controlling apparatus for the high voltage mechanism is indicated at the left of the diagram. This consists essentially of three switches as shown,- each equivalent to a single pole, single throw switch; an indication magnet "I"; and a polarized relay ABC. The indication magnet is operated by current from the motor while the latter acts as a generator immediately after the return of the signal blade to the normal position. The indication magnet picks up a lock which permits the controlling lever to be returned to its normal position after the signal has so returned. The duty of the polarized relay is similar to that of an overload relay, except that its adjustment may be made more accurate than that of the latter.

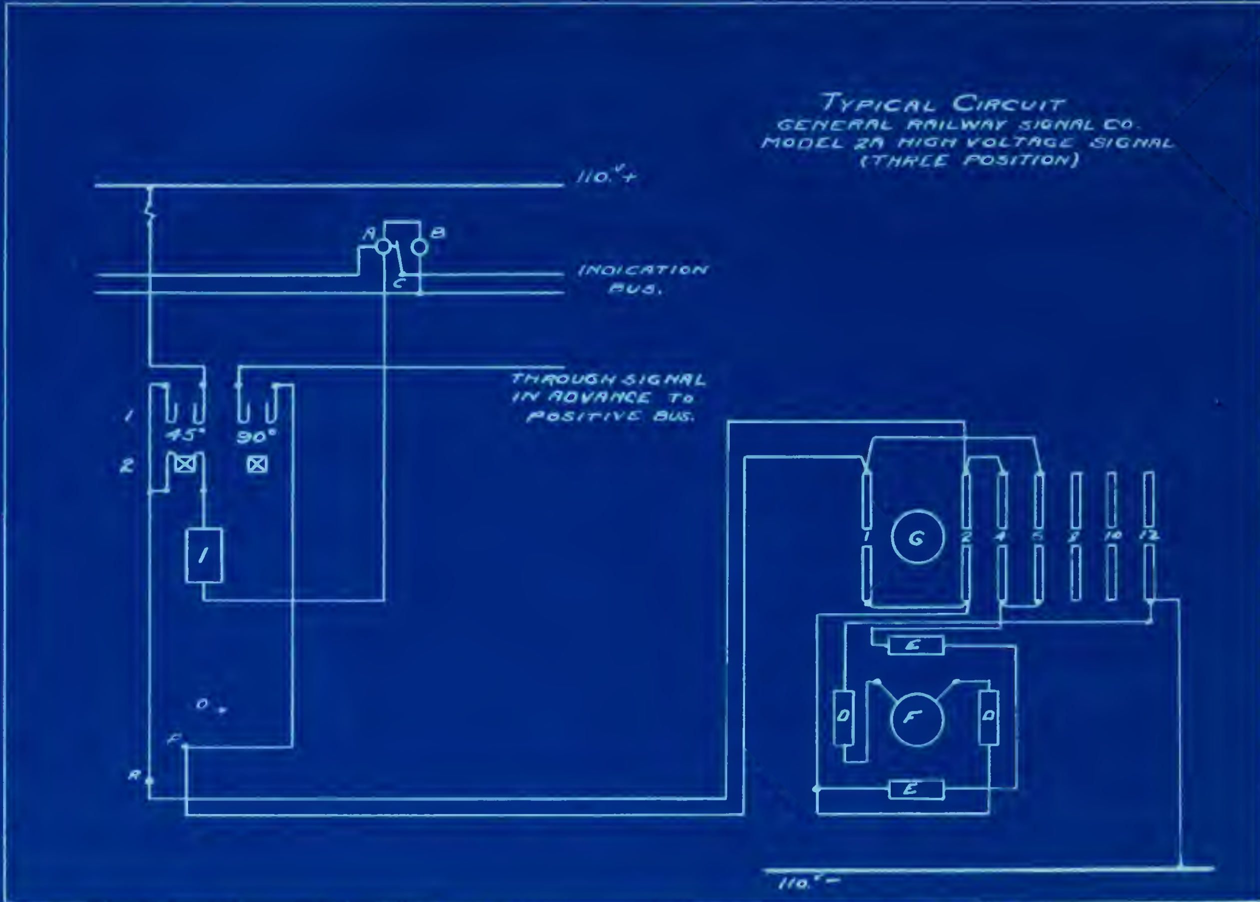
The gears acting between the motor shaft and signal shaft are for the purpose of reducing the motion between motor and signal, Freedom of movement of the motor in the reverse direction after the signal has returned to the normal position is obtained by the use of a ratchet in connection with the gears. In the case of the semaphore signal, the returning torque is obtained from the weight of the blade. In the case of the dwarf signal the returning torque is obtained by the use of two springs connected to the signal shaft.

When the signal turns to the reverse position, one spring is put in tension while the other is put into compression. Thus a torque is set up which brings the signal and mechanism back to the normal position when so desired.

The mechanism so described is designed to operate either a semaphore or rotating disc (dwarf) signal upon a voltage ranging from 110. to 150. volts. Three different high voltage mechanisms were tested. One of these was operated from a voltage near the lower limit, while the other two were operated from voltages near the higher limit. The test of this mechanism consisted od a determinination of the current and voltage variations for succeeding positions of the signal. The retaining current and time of operation were also determined in each case. The current was measured in the lead from common (110V.-), while the voltage was determined between the positive bus (110V. plus) and common; that is, between spring 2 (45°control) ~~and~~ or spring 6 (90°control) and common, as the case may be. The current and voltage variations were determined for operation between danger and 45° position; 45° and 90°; and danger and 90° positions. It was found that the values in the first two sets coincided exactly with the values in the third set, with the ex-

ception of the omission of the initial current value (in the danger to 90°) required to start the motor. In every case such initial current values are shown in parenthesis. An asterisk denotes a uniform variation from the indicated value to the next value. The initial current values are not shown on the curves because of their momentary existence. In order that curves might be plotted showing current and voltage variations with the time of operation and revolutions of the motor, the time of operation was noted between the different variations of current and voltage. The number of revolutions from 0 to 45 as well as from 45 to 90 was also noted.

In each case the current required was found to be greater between 45 and 90 than between 0 and 45. The line drop due to the operating current varied between approximately 1.5% and 4.0% of the impressed line voltage. This, of course, varied with the distance of the mechanism from the source of power, as well as with the interconnection with the other apparatus. The indication current was found to be approximately 0.06 ampere at 15.volts. This current would also vary slightly with the location of the signal.



PAUL A. STRONG

Mechanism tested: Model 2A high voltage signal.

Location: Canal Junction Interlocking Plant, #86.

Current 0 - 90	Current 0 - 45	Current 45-90	Voltage 0 - 90	Voltage 0 - 45	Voltage 45-90
(0.65)	(0.65)	0.24	116.0	116.0	116.0
.55*	.55*	(.65)	111.5	111.5	111.5
.65	.65	.70	116.0	116.0	116.0
.70	.24	.24			
.24					

Retaining current - - - - - - - - - - - - 0.24

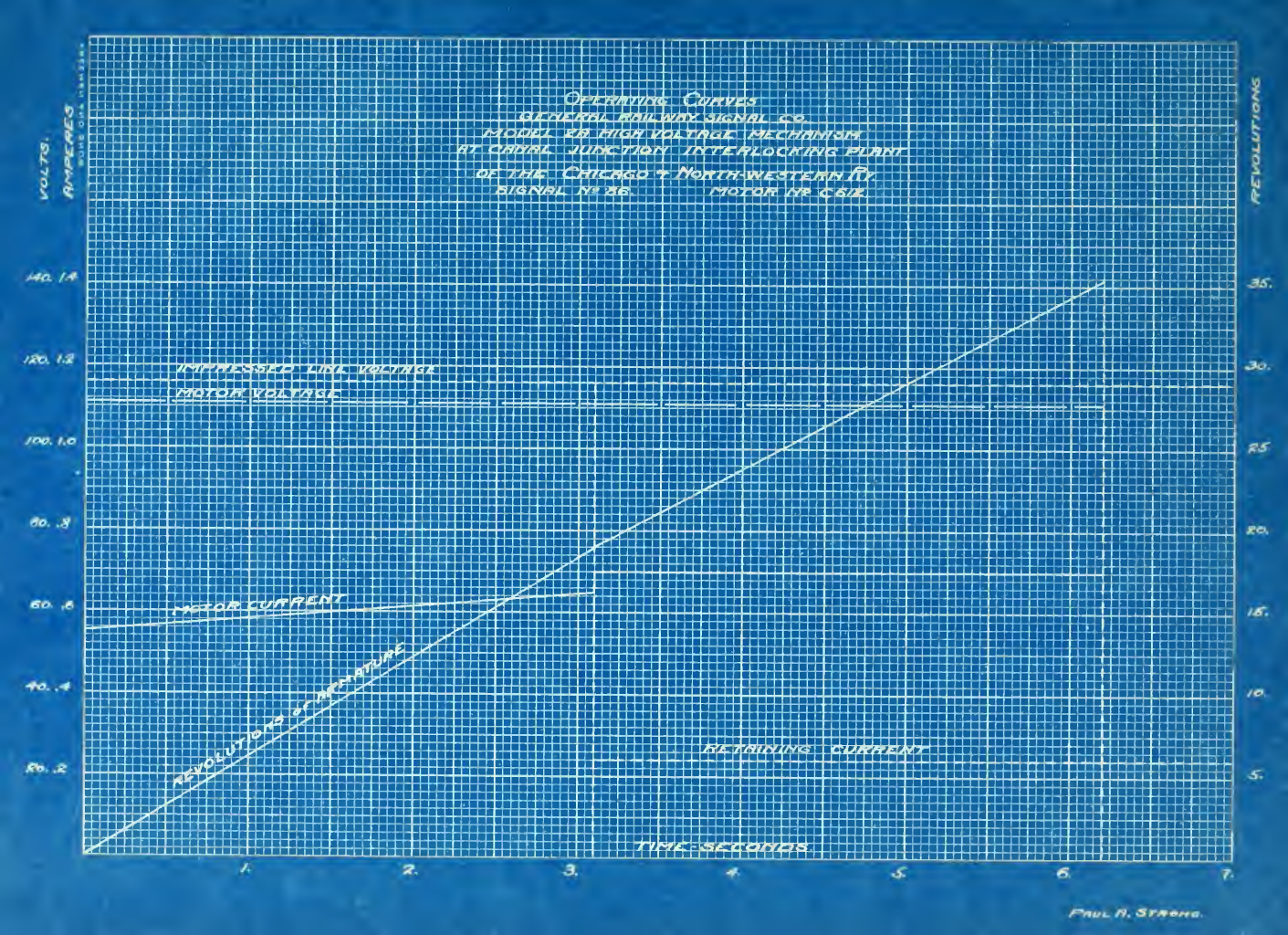
Time (seconds) 0 - 45 - - - - - - - - - - 3.1

" " 45 -90 - - - - - - - - - - 3.1

" " 0 - 90 - - - - - - - - - - 6.2

Revolutions of motor 0 -45 - - - - - -19.0

" " " 45 -90 - - - - - -16.5


OPERATING CURVES
ELECTRIC RAILWAY SIGNAL CO.
MODEL 2B HIGH VOLTAGE MECHANISM
AT CANAL JUNCTION INTERLOCKING PLANT
OF THE CHICAGO & NORTH-WESTERN RY.
SIGNAL No 26. MOTOR HF 602
VOLTS.
AMPERES
REVOLUTIONS
140. 1.4
120. 1.2
100. 1.0
80. .8
60. .6
40. .4
20. .2
35.
30.
25.
20.
15.
10.
5.
IMPRESSED AND NORMAL MOTOR VOLTAGE
MOTOR CURRENT
REVOLUTIONS OF ARMATURE
RETAINING CURRENT
TIME-SECONDS
1.
2.
3.
4.
5.
6.
7.
PAUL A. STRONG.

Mechanism tested: Model 2A high voltage signal.

Location: Lake Street Interlocking Plant #15.

Current 0 -45	Current 45-90	Current 0 -90	Voltage 0 -45	Voltage 45-90	Voltage 0 -90
(0.97)	0.29	(0.97)	140.0	140.0	140.0
.76	(.97)	.76	138.0	137.0	138.0
.29	.88	.88	140.0	140.0	137.0
	.29	.29			140.0

Lock current - - - - - - - - - - - - - - - 0.29

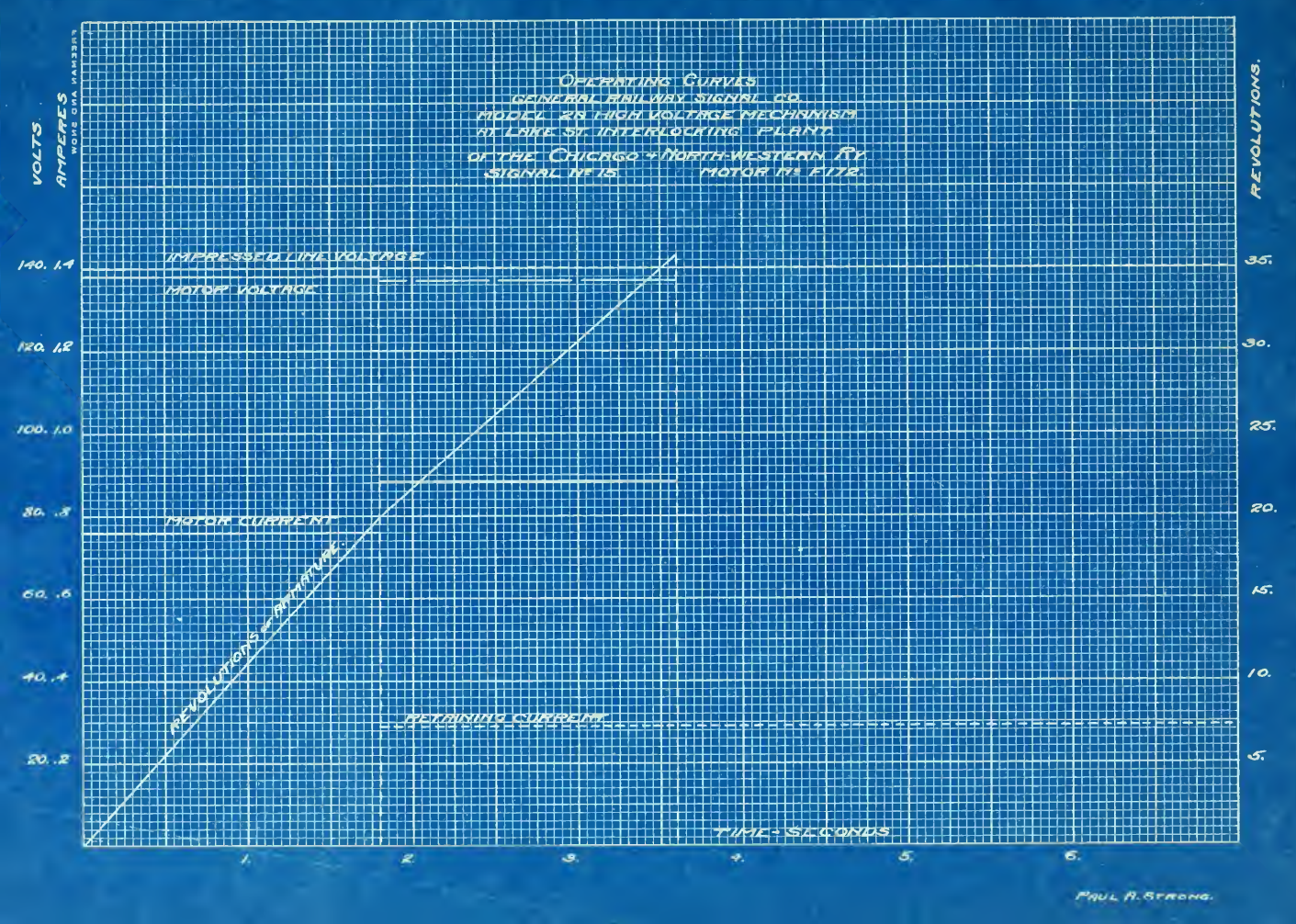
Time (seconds) 0 -45 - - - - - - - - - - - 1.8

" " 45-90 - - - - - - - - - - - 1.8

" " 0 -90 - - - - - - - - - - - 3.6

Revolutions of motor 0 -45 - - - - - - -20.0

" " " 45-90 - - - - - - -16.0


OPERATING CURVES
GENERAL RAILWAY SIGNAL CO.
MODEL 28 MOTOR VOLTAGE MECHANISM
AT LAKE ST. INTERLOCKING PLANT
OF THE CHICAGO & NORTH-WESTERN RY.
SIGNAL No 15 MOTOR No E772
VOLTS
AMPERES
REVOLUTIONS.
140. 1.4
120. 1.2
100. 1.0
80. .8
60. .6
40. .4
20. .2
35.
30.
25.
20.
15.
10.
5.
IMPRESSED ARMATURE VOLTAGE
MOTOR VOLTAGE
MOTOR CURRENT
REVOLUTIONS OF ARMATURE
HOLDING CURRENT
TIME - SECONDS
1.
2.
3.
4.
5.
6.
PAUL A. STRONG.

Mechanism tested: Model 2A high voltage signal.

Location: Lake Street Interlocking Plant #79.

Current 0 -90	Current 0 -45	Current 45-90	Voltage 0 -90	Voltage 0 -45	Voltage 45-90
(1.04)	(1.04)	.29	140.0	140.0	140.0
.80	.80	(1.04)	138.0	138.0	136.0
.92	.29	.92	136.0	140.0	140.0
.29		.29	140.0		

Retaining current - - - - - - - - - - - - 0.29

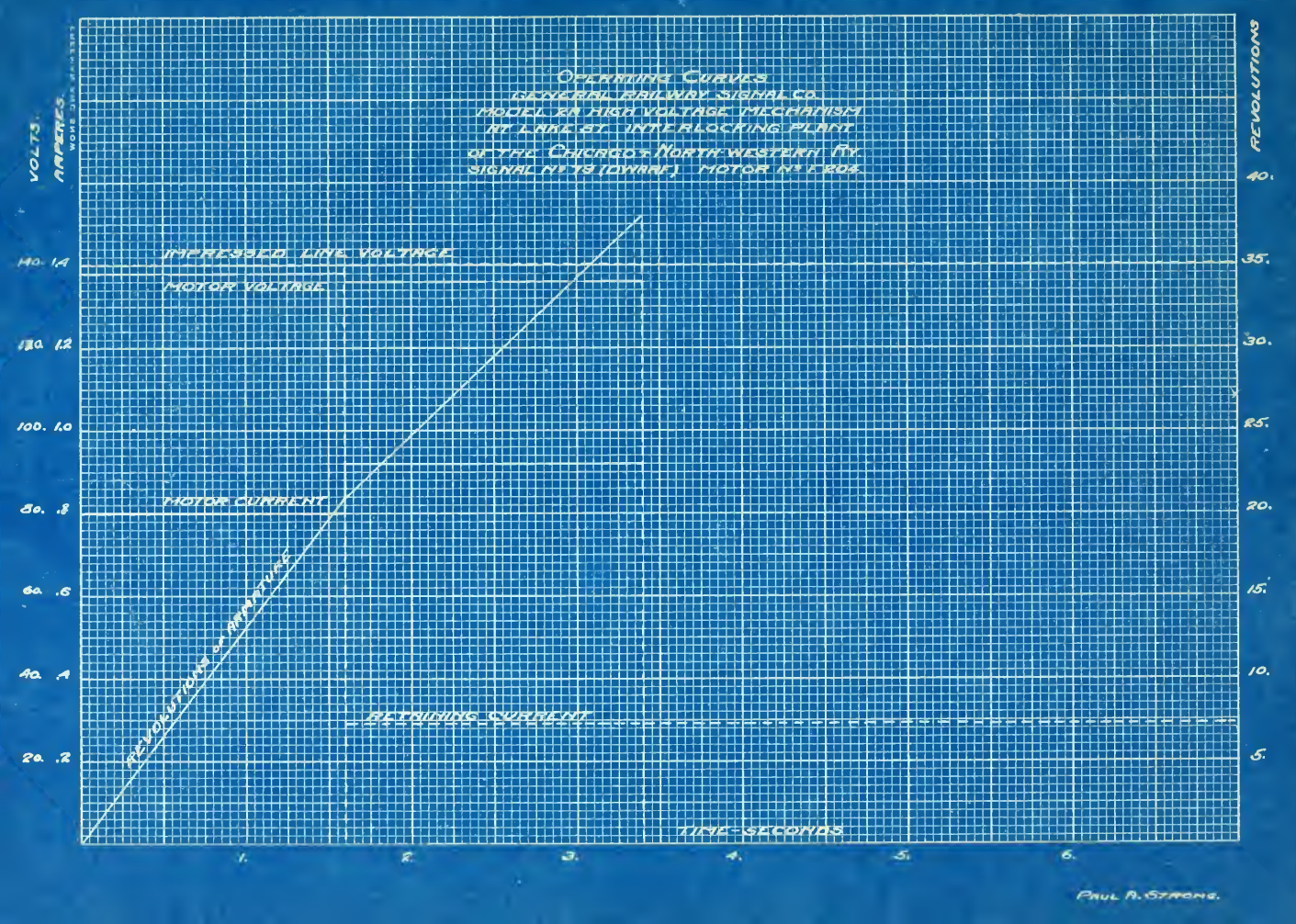
Time (seconds) 0- 45- - - - - - - - - - - 1.6

" " 45-90- - - - - - - - - - - 1.8

" " 0- 90- - - - - - - - - - - 3.4

Revolutions of motor 0 -45 - - - - - - -21.0

" " " 45-90 - - - - - - -17.0


OPERATING CURVES
GENERAL RAILWAY SIGNAL CO.
MODEL 2A HIGH VOLTAGE MECHANISM
AT LAMBERT INTERLOCKING PLANT
AT 115TH, CHICAGO & NORTH WESTERN RY.
SIGNAL No. 19 (OUTWARD) MOTOR No. 1-203
INCREASED LINE VOLTAGE
MOTOR VOLTAGE
MOTOR CURRENT
REVOLUTIONS OF ARMATURE
RETURNING CURRENT
TIME-SECONDS
VOLTS.
AMPERES.
REVOLUTIONS
110. 1.4
100. 1.2
80. 1.0
60. .8
40. .6
20. .4
40.
35.
30.
25.
20.
15.
10.
5.
1.
2.
3.
4.
5.
6.
PAUL R. STRONG.

MODEL 2A LOW VOLTAGE MECHANISM.

This mechanism, as shown, differs only slightly from the high voltage mechanism of the same model. Inasmuch as it is designed for automatic work where the power must be supplied from battery only, it is equipped with a retaining mechanism which requires a much smaller amount of power than that of the high voltage mechanism. The motor is a four-pole series motor designed to operate on 10. to 15,volts. The circuit breaker is essentially the same as that already described, with the exception that all contacts are arranged to drag, instead of being provided with a quick break.

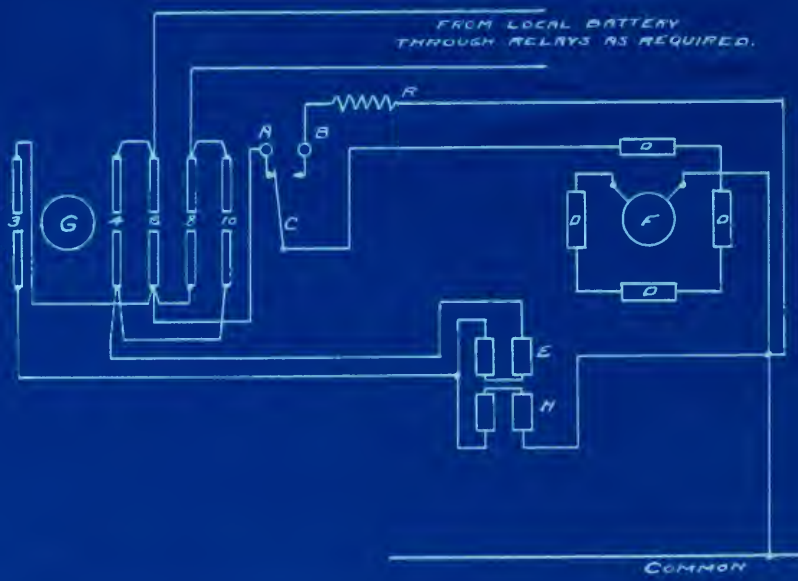
The retaining mechanism consists of two sets of coils, E and H;- E being of comparatively high resistance and H of comparatively low resistance. H is first energised, exerting a strong force which picks up the armature of the magnet. The moment the armature is picked up, the circuit is broken through H and closed through E and H in series. This retaining force is sufficient to hold up the armature of the magnet, although it is not sufficient to pick it up. The introduction of the high resistance E accordingly cuts down the current consumption considerably, as may be seen by reference to the accompanying curves.

The double-throw switch ABC is designed to make at AC during the clearing of the signal, and to make at BC just before the signal reaches the danger poaition. This last connection short-circuits the motor through the resistance R, thus preventing jar to the apparatus.

In the tests of this mechanism the current values were determined in the lead joining common, while the voltage values were determined from contacts 4 and 8 respectively to common, depending upon the position of the signal arm. The variations were timed in the same manner as in the case of the high voltage tests.

The resulting curves for the low voltage mechanism are slightly different in form from those of the high voltage mechanism because of the retaining coils being connected in multiple across the line, instead of series; together with the fact that these coils are not shorted in passing from 0 to 90. Hence the duration of the current in the retaining coils is noticed on the curves. The line drop during operation varies from 20.% to 30.% of the normal line voltage.

Typical Circuit
GENERAL RAILWAY SIGNAL CO.
MODEL 2A LOW VOLTAGE SIGNAL
(THREE POSITION)



PAUL M. STRONG.

Mechanism tested: Model 2A low voltage signal.

Location: Central Street Bridge, Evanston Illinois,

Current 0 -45	Current 45-90	Current 0 -90	Voltage 0 -45	Voltage 45-90	Voltage 0 -90
(1.80)	(2.60)	(1.80)	(8.0)	(8.1)	(8.0)
1.40*	2.10*	1.40*	9.1*	8.4*	9.1*
1.90	2.40	1.90	8.5	8.1	8.5
2.40	.015	2.40	10.3	10.3	(8.1)
.015		2.10*			8.40*
		2.40			8.10
		.015			10.3

Retaining current - - - - - - - - - - - - 0.015

Time 0 45 - - - - - - - - - - - - - - - - 5.2

" 45 90- - - - - - - - - - - - - - - - 6.2

" 0 90 - - - - - - - - - - - - - - - - 11.4

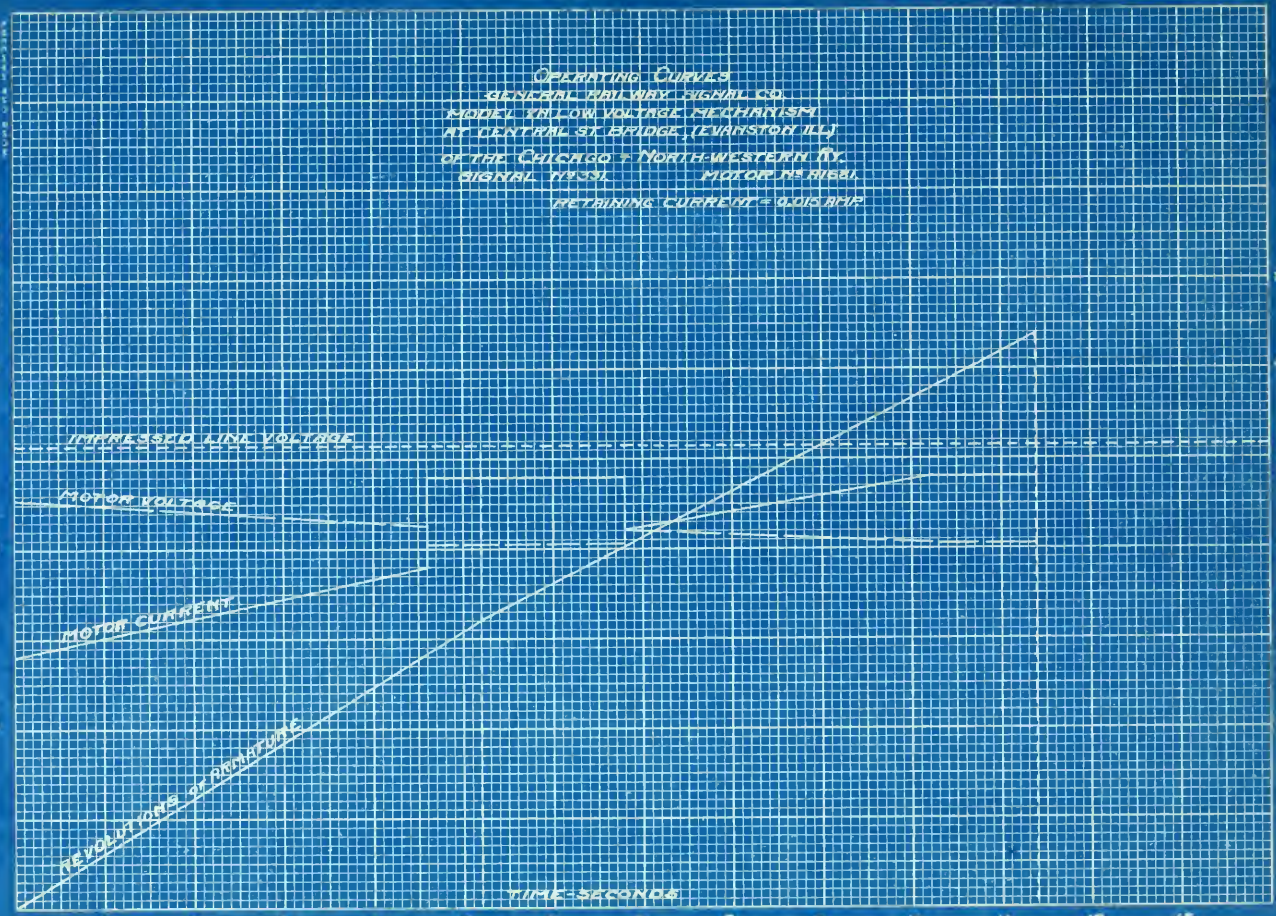
Time to 45 lock - - - - - - - - - - - 4.6

" " 90 " - - - - - - - - - - - - 10.2

" through 45 lock - - - - - - - - 6.8

Revolutions of motor 0 45 - - - - - - 16.0

" " " 45 90 - - - - - 16.0



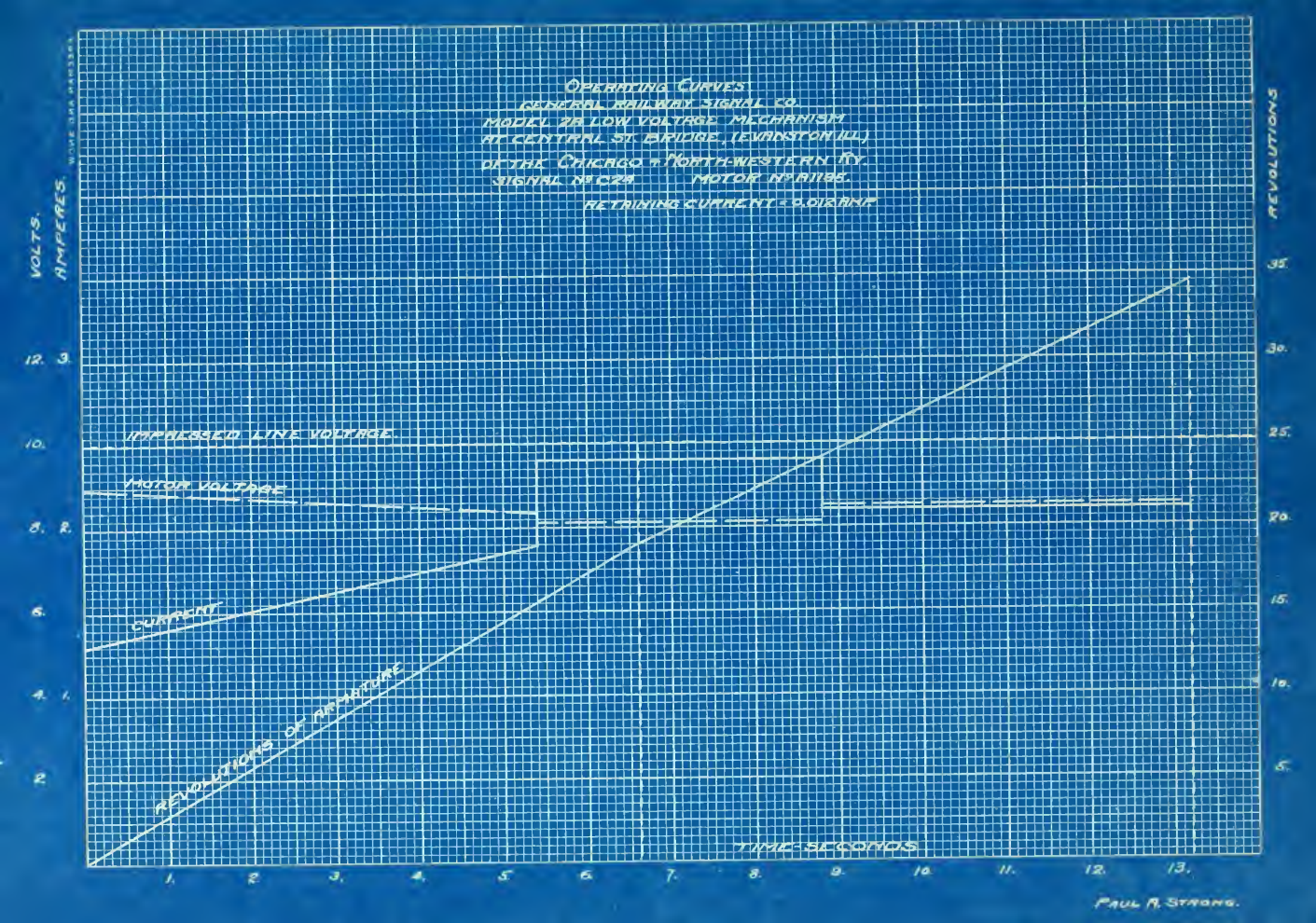
PAUL A. STRONG.

Mechanism tested: Model 2A low voltage signal.

Location: Central Street Bridge, Evanston Illinois.

Current 0 45	Current 45 90	Current 0 90	Voltage 0 45	Voltage 45 90	Voltage 0 90
(1.70)	(2.50)	(1.70)	(8.0)	(7.80)	(8.0)
1.30*	2.10	1.30*	8.9*	8.40	8.9*
1.90	2.40	1.90	8.3	10.00	8.3
2.40	.012	2.40	8.1		8.1
.012		2.10	10.0		8.4
		2.40			10.0
		.012			

Retaining current	0.012
Time 0 45	6.6
" 45 90	7.5
" 0 90	14.1
Time to 45 lock	5.4
" " 90 "	13.2
" through 45 lock	8.8
Revolutions of motor 0 45	19.0
" " " 45 90	15.5


OPERATING CURVES
GENERAL RAILWAY SIGNAL CO.
MODEL 2A LOW VOLTAGE MECHANISM
AT CENTRAL ST. BRIDGE, (EVANSTON, ILL.)
OF THE CHICAGO & NORTH-WESTERN RY.
SIGNAL NO. C-28 MOTOR NO. A1186.
RETAINING CURRENT = 0.012 AMP.
VOLTS.
AMPERES.
REVOLUTIONS
UNREGULATED LINE VOLTAGE
MOTOR VOLTAGE
CURRENT
REVOLUTIONS OF ARMATURE
TIME: SECONDS
12. 3.
10.
8. 2.
6.
4. 1.
2.
35.
30.
25.
20.
15.
10.
5.
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13.
PAUL A. STRONG.

Mechanism tested: Model 2A low voltage signal.

Location: Central Street Bridge, Evanston Illinois.

Current 0 45	Current 45 90	Current 0 90	Voltage 0 45	Voltage 45 90	Voltage 0 90
(1.85)	(2.60)	(1.85)	(7.3)	(6.8)	(7.3)
1.15*	2.15	1.15*	8.5*	7.7	8.5*
2.05	2.55	2.05	7.8	7.35	7.8
2.50	.010	2.50	7.45	10.2	7.45
.010		2.15	10.2		7.65
		2.55			7.35
		.010			10.2

Retaining current - - - - - - - - - - - - 0.010

Time 0 45 - - - - - - - - - - - - - - - 6.6

" 45 90 --- - - - - - - - - - - - - 7.0

" 0 90 - - - - - - - - - - - - - - - 13.6

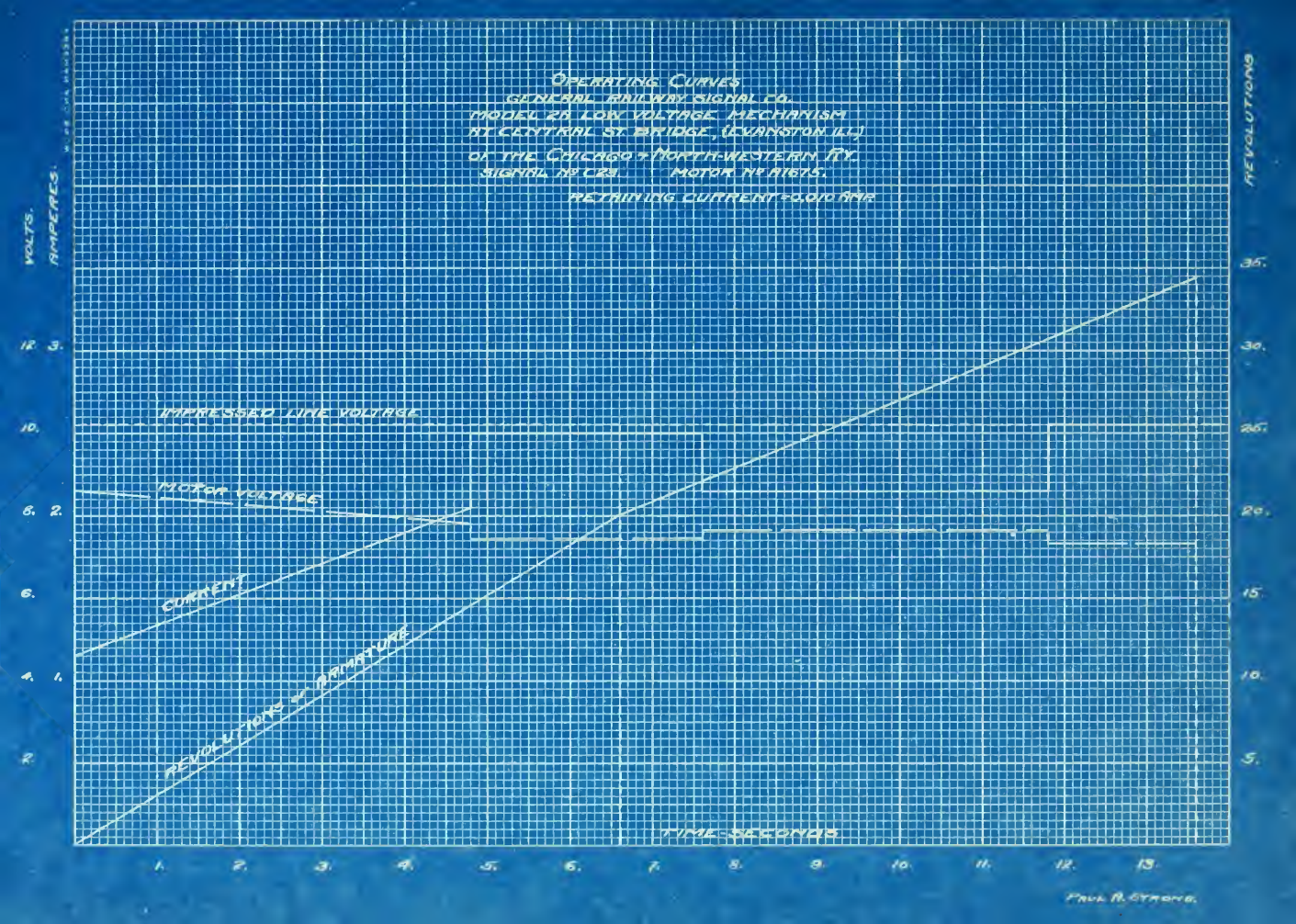
Time to 45 lock - - - - - - - - - - - 4.8

" " 90 " - - - - - - - - - - - 11.8

" through 45 lock - - - - - - - - 7.6

Revolutions of motor 0 45 - - - - 20.0

" " " 45 90 - - - - 14.5

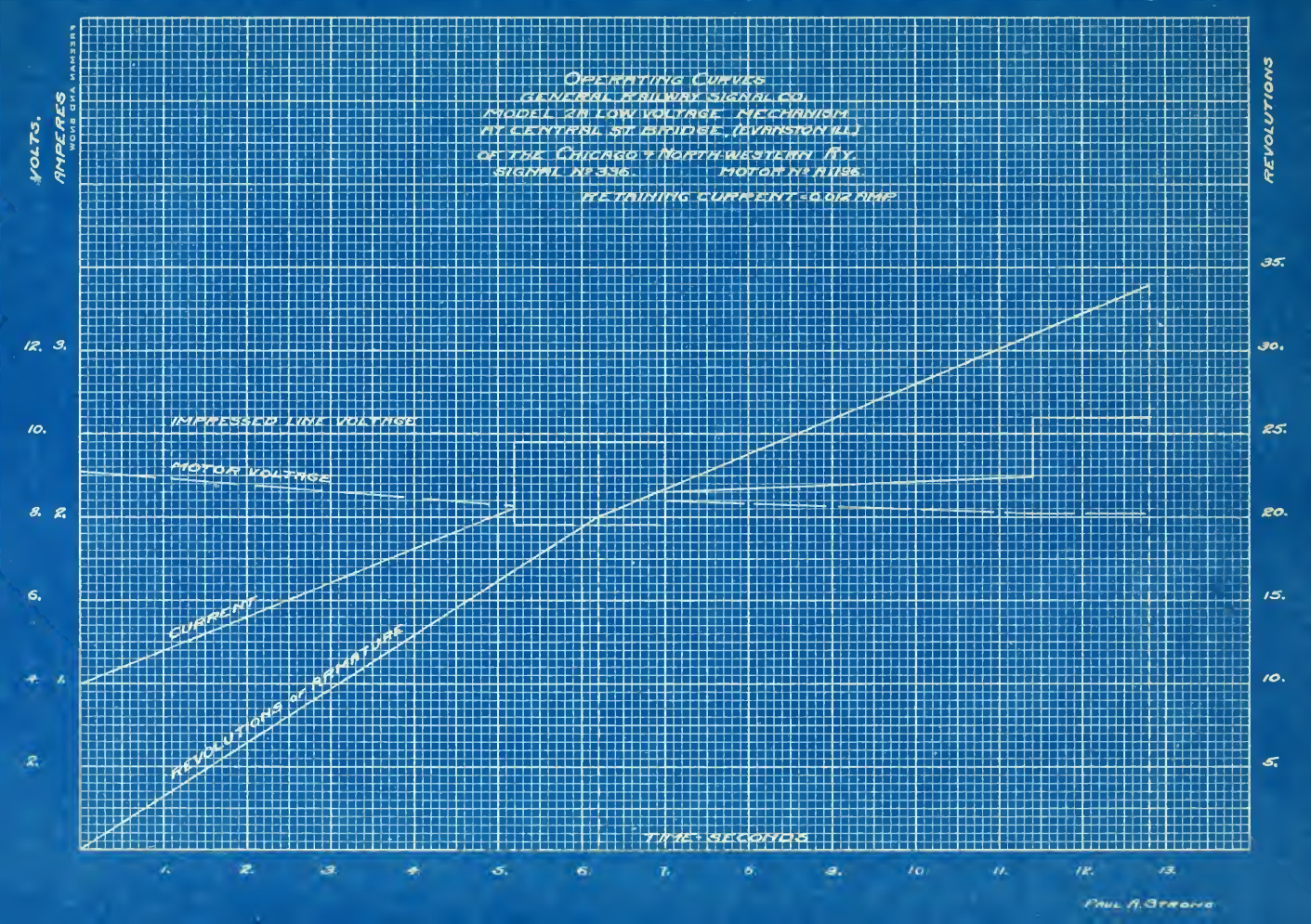

Operating Curves
General Railway Signal Co.
Model 23 Low Voltage Mechanism
at Central St. Bridge, Evanston Ill.
of the Chicago & North-Western Ry.
Signal No C23 Motor No A1675.
Retaining current 2.0 to 2.5 Amp.
Volts.
Amperes.
Revolutions
Impressed Line Voltage
Motor Voltage
Current
Revolutions of Armature
Time-Seconds
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13.
12. 3.
10.
6. 2.
6.
4. 1.
2.
35.
30.
25.
20.
15.
10.
5.
Paul R. Strong.

Mechanism tested: Model 2A low voltage signal.

Location: Central Street Bridge, Evanston Illinois.

Current 0 45	Current 45 90	Current 0 90	Voltage 0 45	Voltage 45 90	Voltage 0 90
(1.80)	(2.65)	(1.80)	(8.0)	(7.8)	(8.0)
1.00*	2.15*	1.00*	9.1*	8.4*	9.1*
2.05	2.25	2.05	8.25	8.1	8.25
2.45	2.60	2.45	7.8	10.0	7.8
.012	.012	2.15*	10.05		8.4*
		2.25			8.1
		2.60			10.0
		.012			

Retaining current - - - - - - - - - - - -	0.012
Time 0 45 - - - - - - - - - - - - - - -	6.2
" 45 90 - - - - - - - - - - - - - - -	6.6
" 0 90 - - - - - - - - - - - - - - -	12.8
Time to 45 lock - - - - - - - - - - - -	5.2
" :" 90 " - - - - - - - - - - - - -	11.4
" through 45 lock - - - - - - - - - -	7.0
Revolutions of motor 0 45 - - - - - - -	20.0
" " " 45 90 - - - - - - -	14.0

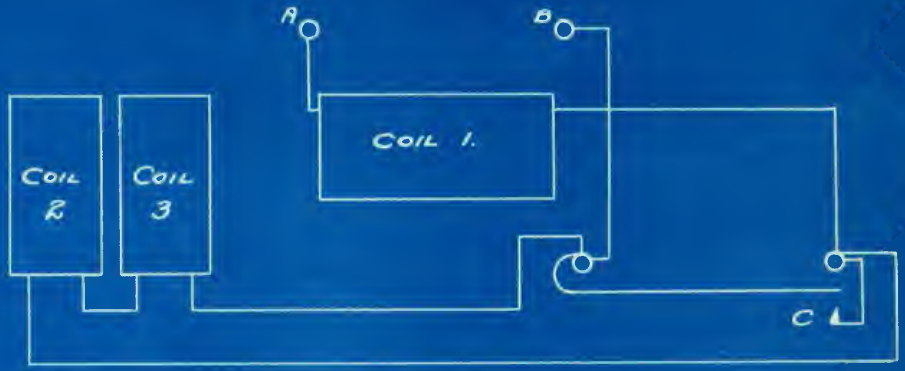

OPERATING CURVES
GENERAL RAILWAY SIGNAL CO.
MODEL 2A LOW VOLTAGE MECHANISM
AT CENTRAL SW. BRIDGE, EVANSTON ILL.
OF THE CHICAGO & NORTH WESTERN RY.
SIGNAL NO 336. MOTOR NO A1136.
RETAINING CURRENT = 0.012 AMP
VOLTS.
AMPERES
REVOLUTIONS
IMPRESSED LINE VOLTAGE
MOTOR VOLTAGE
CURRENT
REVOLUTIONS OF ARMATURE
TIME: SECONDS
12.
10.
8.
6.
4.
2.
3.
2.
35.
30.
25.
20.
15.
10.
5.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
PAUL A. STROHL

HALL SIGNAL MECHANISM.

The Hall signal mechanism is operated by the use of two magnetic fields as shown. Coil 1 is of low resistance (about 40.ohms), while coils 2 and 3 each have a value of approximately 200. ohms. Contact C is closed except when the signal is held at "clear" position. The signal itself consists of a counterbalanced silk disc (red or green) which is brought into view or hidden from view, as the case requires. The disc is mo moved by the armature of coill1, and held in the clear position by the armatures of coils 1,2, and 3. Current is supplied through terminals A and B. The low resistance of coil 1 affords a strong magnetic field which picks up its armature and clears the signal. At the moment the signal is cleared the contact C is opened, throwing the three coils in series, and hence cutting down the retaining current considerably.

The results of these six tests show a comparatively large operating current and a comparatively small retaining current. The minimum current required for pickup is in each case approximately three times the retaining current. This minimum current merely clears the signal and does not produce satisfactory operation. Neglecting slight oscillations, the time for going to clear and going to danger is the same, varying from 1.5 to 1.8 seconds.

Typical Circuit
Hall Signal Co.
(Home and Distant Signals)



Paul A. Strong.

Mechanism tested: Hall signals.

Location: Rogers Park Station, Chicago Illinois.

No.	Type	Operating current	Operating voltage	Retaining current
317	Distant	0.2300	7.8	0.2300
315	Home	.2360	12.6	.0327
C09	Home	.3323	23.0	.0511
C08	Distant	.1789	10.5	.0256
318	Distant	.2045	11.5	.0286
320	Home	.2658	13.7	.0368

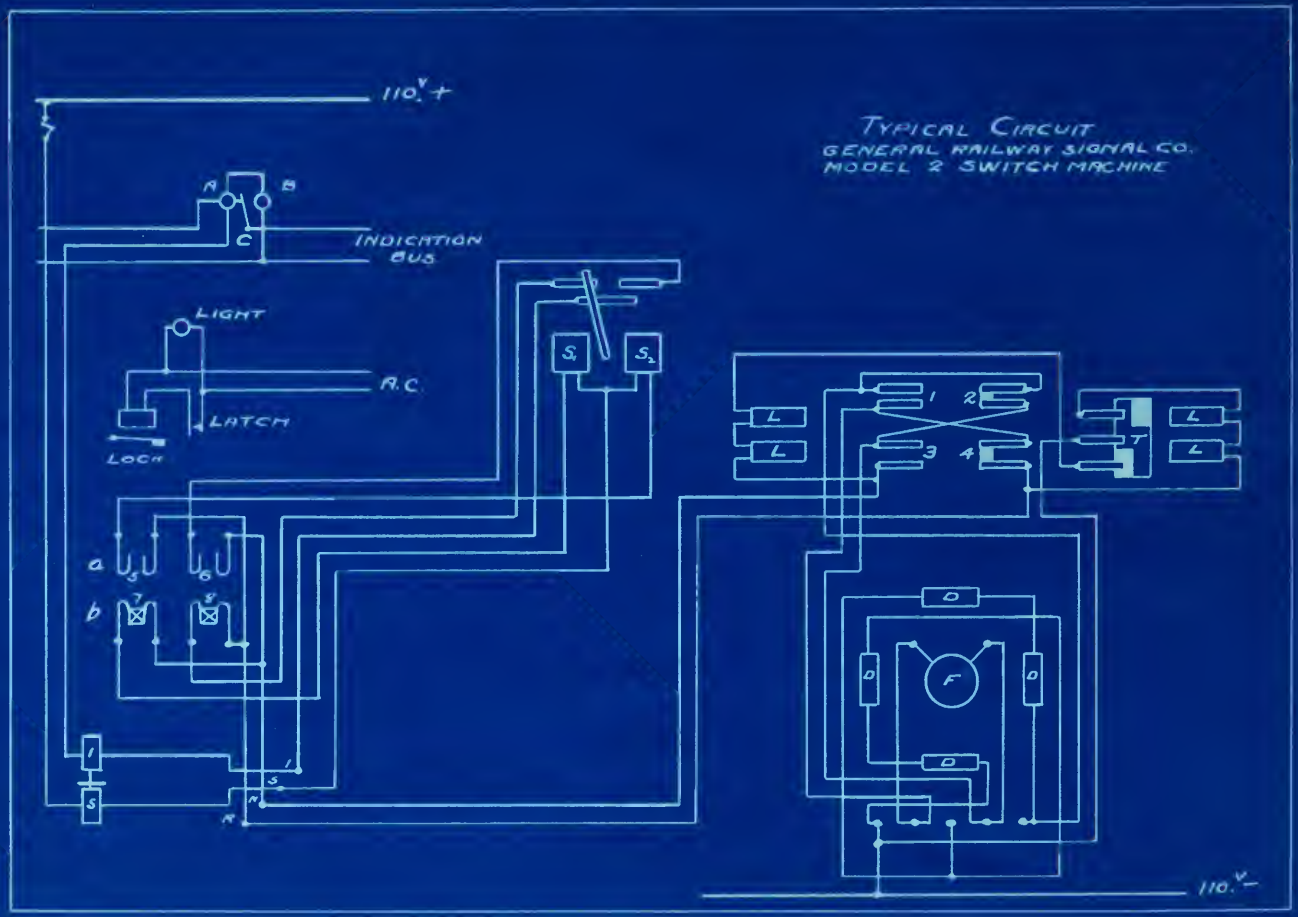
No.	Minimum pickup	Time to clear	Time to danger
317	0.0818	1.6	1.6
315	.1125	1.5	1.5
C09	.1820	1.5	1.5
C08	.1329	1.8	1.8
318	.0920	1.6	1.6
320	.1023	1.5	1.5

Note: Contact shorting coils 2 and 3 did not make when signal was at danger. Signal #317.

MODEL 2 SWITCH MACHINE.

The operation of the model 2 switch machine may be divided inxto three distinct parts, as (a) unlocking of switch, (b) throwing of switch, (c) locking of switch. These three operations are accomplished by means of cams, which in turn are attached to gears to permit of reduction of motion between motor and switch.

In connection with the four pole, series motor is operated a pole changing device. This is operated mechanically and is held magnetically by the four magnets LLLL. The operation is to shift the connections from 2 and 4 over to 1 and 3 at the end of a switch movement, thus preparing the motor for the opposite operation. The rocker T is also shifted so as to energize the proper set of coils. The wiring at the controlling lever is also shown in the diagram. This consists of two power switches, 5 and 7, and two indication switches, 6 and 8. The selector S_1S_2 shifts the indication circuit between 6 and 8 as required by the position of the switch. The coils I and S operate a lock which permits the lever to be returned to the proper position after the movement of the switch. The test was made by taking the current in the lead from common, and the voltage from 3 or 4 to common, as required. A single



Typical Circuit
General Railway Signal Co.
Model 2 Switch Machine

Paul A. Strong.

Mechanism tested: Model 2 switch machine.

Location: Clinton Street Interlocking Plant # 146.

Current variations:

(Fields in series) (7.3) 5.1

" " multiple) (10.2) 7.0

Voltage variations: Line voltage = 142.

(Fields in series) (142.) 137.

" " multiple) (142.) 135.

Time of operation:

Series fields 1.4 seconds,

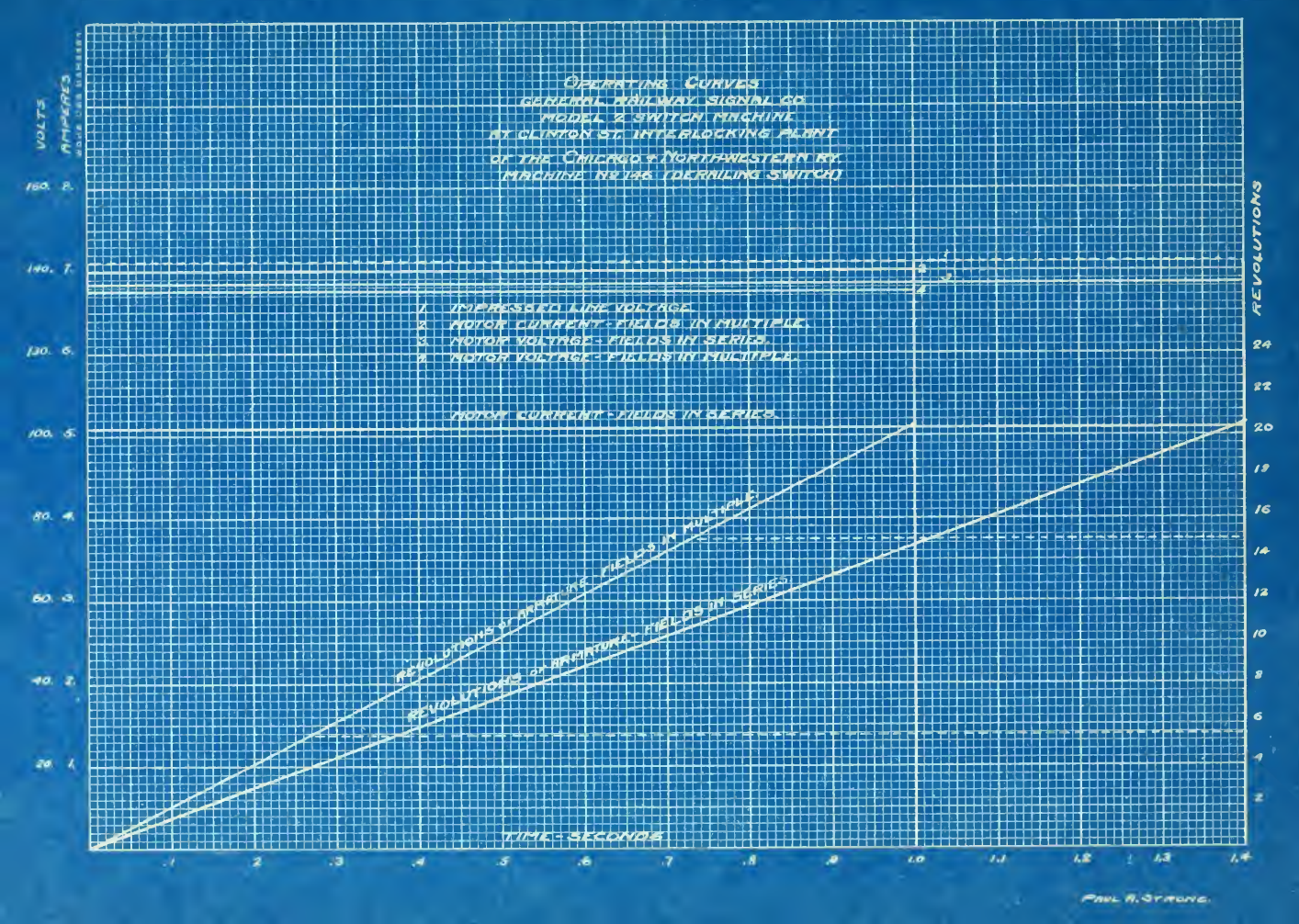
Multiple fields 1.0 "

Total revolutions = 20.5

Revolutions to unlock = 5.5

" " throw = 9.5

" " lock = 5.5

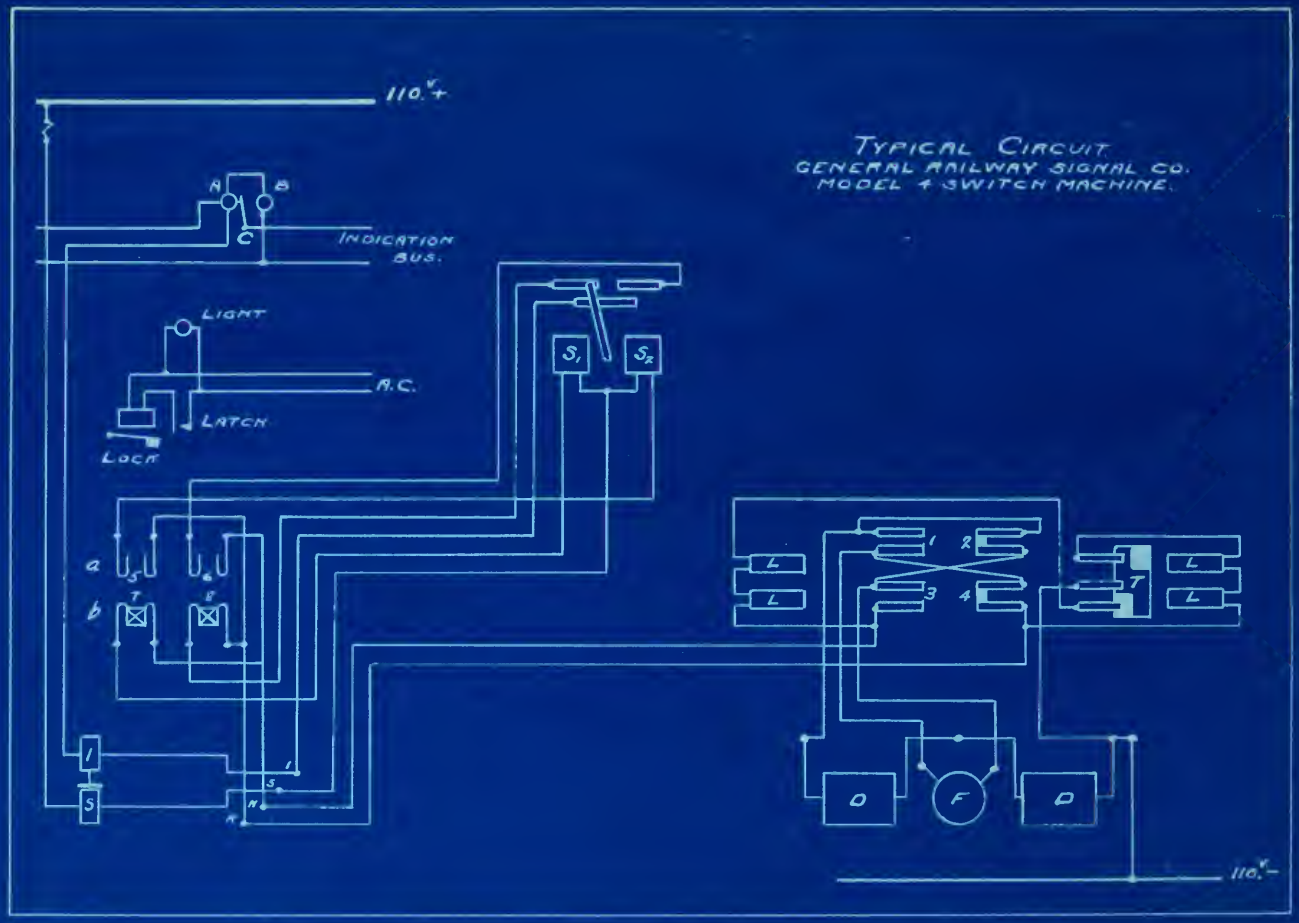


PAUL A. STRONG.

value of current and of voltage was found to exist throughout the movement of the switch. The series operation of the switch, completed in 1.4 seconds, required a current of 5.1 amperes; while the multiple operation, completed in 1.0 second, required a current of 7.0 amperes. The normal line voltage had the value 142. volts, hence the series operation caused a line drop of 3.5% and the multiple operation caused a line drop of 5.0%. The initial current value required to start the motor is also given in parenthesis, but is not shown on the curve because of its momentary existance.

MODEL 4 SWITCH MACHINE.

The model 4 switch machine differs from the model 2 only in construction. Where, in the case of the model 2 machine the motor and operating gears are mounted separately;- in the case of the model 4 machine the motor and gears are cast and put together as a unit, thus affording greater solidity and strength. The switch and lock rod are both cam operated as before. The motor here used is a four pole, series motor, having, however, only two of these poles excited. The excited poles are on diametrically opposite sides of the armature and are of the same polarity.



TYPICAL CIRCUIT
GENERAL RAILWAY SIGNAL CO.
MODEL 4 SWITCH MACHINE.

PAUL A. STRONG.

Mechanism tested: Model 4 switch machine.

Location: Clinton Street Interlocking Plant #133.

Current variations:

(Fields in series) (7.7) 4.0 5.0

" " multiple) (10.2) 5.2 5.5

Voltage variations: Line voltage = 142.

(Fields in series) (142) 133.

" " multiple) (142) 132.

Time of operation:

Series fields 2.0 seconds.

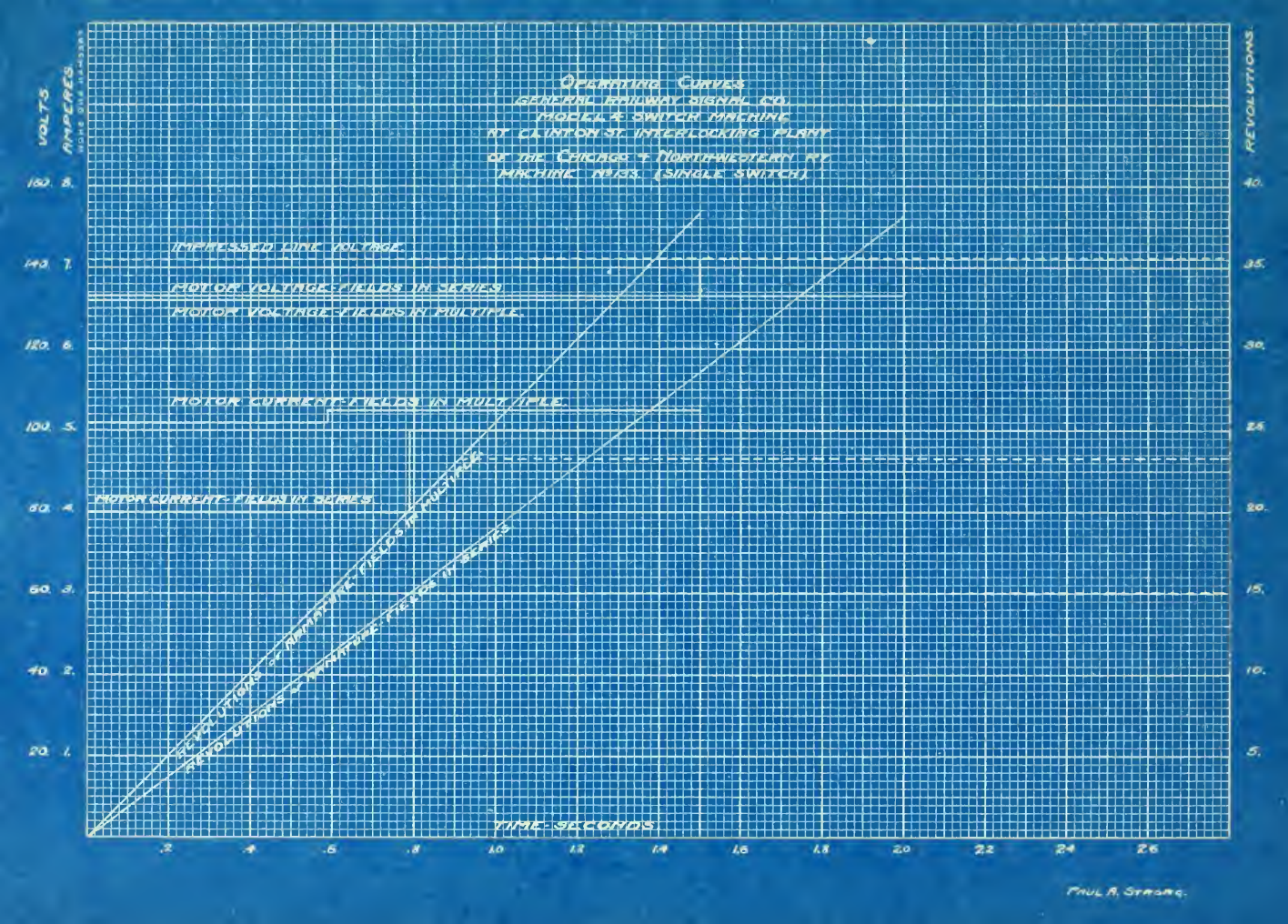
Multiple fields 1.5 "

Total revolutions = 38.25

Revolutions to unlock = 15.00

" " Throw = 8.25

" " lock = 15.00


Operating Curves
General Railway Signal Co.
Model A Switch Machine
at Clinton St. Interlocking Plant
of the Chicago & North Western Ry.
Working Rods. (Single Switch)
Volts
Amperes
Revolutions.
Time-Seconds
Impressed Line Voltage.
Motor Voltage-Fields in Series.
Motor Voltage-Fields in Multiple.
Motor Current-Fields in Multiple.
Motor Current-Fields in Series.
Revolutions-Fields in Multiple.
Revolutions-Fields in Series.
Paul A. Strang.

The test was carried out by determining the current variations in the lead to common, and the voltage variations from 3 or 4 to common, as required. In the case of series and multiple operation the current values showed an increase the moment the switch points began to move. This current value continued throughout locking after the movement of the point. The voltage showed a line drop of 6.3% for series operation and 7.0% for multiple operation from the line voltage of 142. volts.

TRACK CIRCUITS.

The storage-battery track circuits tested were each fed from one-cell storage-batteries. These batteries fed into continuous sections of track having a length of 1300. feet each. This track was rock ballast and in good condition. The resistance noted was that used in series with the battery to cut the voltage from that of the battery to a value of approximately 0.5 volt at the track. The current through the circuit for conditions of clear track showed values of approximately 0.14 ampere.

For conditions of shorted track, that is, train on track, the current value was approximately

Track circuit data.

Storage battery circuits, Galena Division Bridges D-E-F.

No.	Bridge	Track	Resistance	Current
1	E-F	4	10.	0.14
2	D-E	4	10.	0.14
3	D-E	3	10.	0.12
4	E-F	2	10.	0.14
5	D-E	2	10.	0.14
6	D-E	1	7.	0.12

No.	Current short	Voltage track	Voltage short	Voltage battery
1	0.19	0.50	0.05	2.00
2	.19	.50	.05	1.95
3	.16	.50	.05	1.70
4	.16	.55	.05	1.95
5	.19	.50	.05	1.95
6	.155	.45	.05	1.30

Lake Street Interlocking Plant.

Track	Track voltage	Current
181	1.62	0.160
182	2.2	.125
208	2.42	.117
209	2.54	.113

Track circuits: Lake Street (continued)

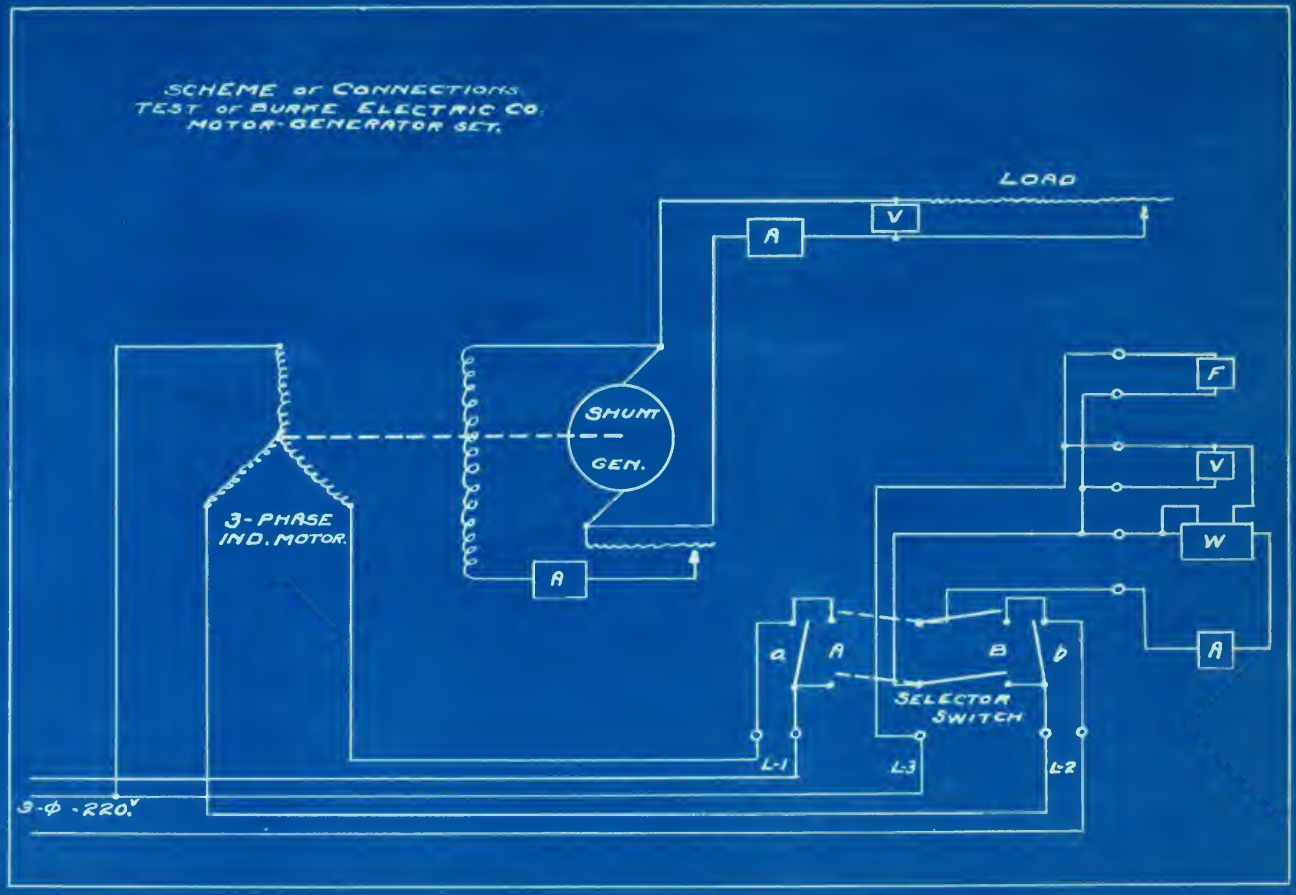
Track	Track voltage	current
210	2.26	0.102
211	2.26	.099
212	2.66	.113
147	2.07	.117
178	2.42	.230
11	2.23	.124
10	2.14	.120
164	1.68	.120
185	2.30	.114
201	2.32	.111
192	2.10	.103
193	1.96	.104
204	2.24	.099
188	2.06	.099
205	2.50	.116
183	2.00	.135
172	1.98	.111
175	1.94	.320
177	2.16	.130

0.19 ampere, while the track voltage in each case fell to 0.05 volt. The length of train had no effect upon the values of short circuit current and voltage.

The track circuit current and voltage values found at the Lake Street Interlocking Plant showed an average value of track voltage of approximately 2.2volts and an average value of track current of approximately 0.12 ampere. The track was in good condition during the test, but the rock ballast was wet from melted snow.

TEST OF MOTOR-GENERATOR SETS.

The motor-generator sets tested are used for charging high and low voltage storage batteries, whence the power for operating the apparatus is obtained. These batteries are floated across the line and so are being charged when no current is being drawn from the line. The pressure of the high voltage battery is maintained at approximately 145 volts, and that of the low voltage battery at approximately 24.5 volts. Hence the tesst were carried out with this in mind. In every case the performance indicated is that of the induction motor and shunt generator combined. The efficiency test is



PAUL A. STRONG.

given to determine the efficiency under load conditions with a constant impressed voltage. The field resistance was varied in order to maintain this voltage. The load characteristics are given to show the performance of the set as actually used; that is, with constant field resistance giving full voltage at no load.

The scheme of connections for the test is shown herewith. The A.C. power input was determined in each case by the use of the selector switch and one wattmeter. This is equivalent to the use of two wattmeters without the switch, The method is to take the current for the wattmeter in two lines of the three-phase line, and the pressure in each case to the third line. The sum of these two meter readings is then the total power consumed. The D.C. power output was determined by the use of an ammeter in series with the load and a voltmeter across the load.

NOTE. All meter readings given in the preceding data have been corrected by the use of instrument calibration curves.

Efficiency tests of motor generator sets.

110. - 150.-volt set.

** Voltage line	A.C. Frequency E.M.F.	** Power input.	** Voltage line	D.C. ** Current	No.
192.	60.5	11454.	148.	56.5	1
194.	"	10004.	"	50.0	2
197.	"	7950.	"	40.5	3
198.	"	5700.	"	28.0	4
198.4	"	4260.	"	19.5	5
198.4	"	3350.	"	12.5	6
200.	"	2674.	"	7.4	7
200.	"	2010.	"	3.5	8
200.4	"	1550.	"	0.0	9

10. - 30.-volt set.

204.	60.5	510.	24.5	0.0	1
204.	"	620.	"	6.0	2
204.	"	760.	"	9.4	3
204.	"	820.	"	14.0	4
203.	"	1110.	"	22.5	5
203.	"	1220.	"	28.0	6
202.	"	1530.	"	38.0	7
201.	"	1720.	"	45.0	8
201.4	"	2390.	"	58.0	9
201.	"	2960.	"	66.0	10

Motor-generator sets (continued)

No.	Current field	armature speed	Power output	per cent efficiency
1	1.58	1620.	8360.	73.0
2	1.45	1665.	7400.	74.0
3	1.38	1712.	6000.	75.4
4	1.30	1763.	4145.	72.8
5	1.20	1763.	2885.	66.9
6	1.16	1763.	1851.	55.3
7	1.12	1784.	1097.	41.0
8	1.10	1763.	518.	25.7
9	1.08	1763.	0.	0.0
1	1.20	1742.	0.	0.0
2	1.45	1742.	147.	23.7
3	1.50	1722.	230.	30.3
4	1.51	1722.	343.	41.8
5	1.67	1722.	551.	50.0
6	1.75	1719.	685.	57.1
7	2.01	1715.	930.	60.7
8	2.11	1711.	1100.	63.9
9	2.60	1700.	1420.	59.4
10	2.95	1650.	1616.	54.6

Magnetization Characteristics: Motor-generator sets.

110. - 150.-volt sets

A.C. Voltage line	Frequency	D.C. Terminal E.M.F.	Current field	Speed
201.	61.0	149.0	1.19	1830.
201.	"	143.0	1.07	"
201.	"	134.0	.90	"
201.	"	122.0	.80	"
200.	"	109.0	.70	"
200.4	"	101.0	.60	"
201.	"	85.0	.50	"
200.	"	77.0	.40	"
201.	"	69.0	.36	"

10. - 30.-volt set

202.	60.0	41.0	5.20	1740.
202.4	"	35.5	2.70	"
202.	"	31.0	1.81	"
204.	"	26.0	1.30	"
203.	"	18.2	.81	"
203.4	"	13.0	.50	"
203.	"	8.3	.30	"
204.	"	6.0	.21	"

Load Characteristics: Motor-generator sets.

110. - 150.-volt set.

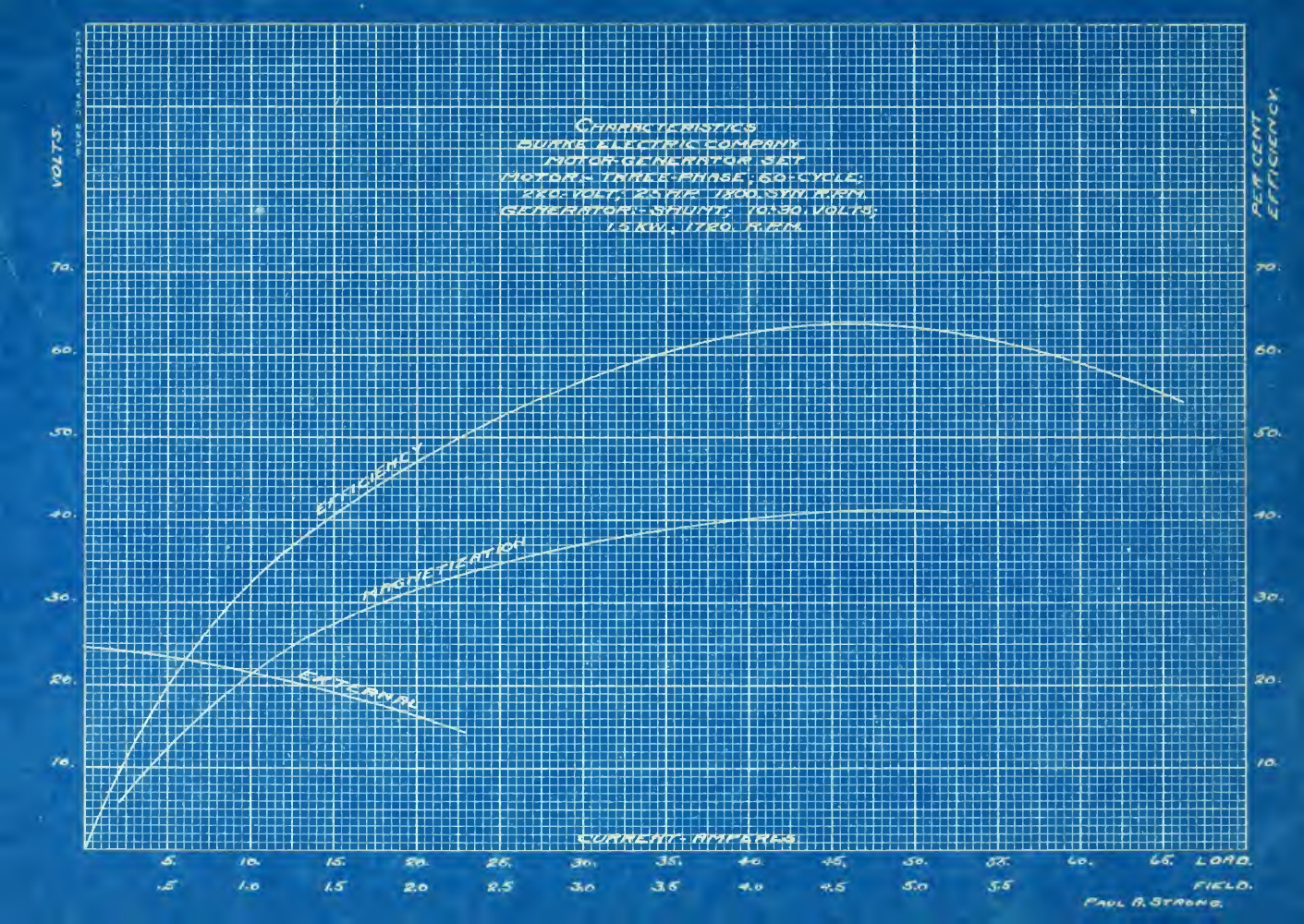
** Voltage line	A.C. Frequency E.M.F.	** Power input	No.
200.6	60.75	1550.	1
200.	"	2000.	2
199.	"	2380.	3
198.6	"	3080.	4
198.	"	3840.	5
197.6	"	4580.	6
198.	"	5470.	7
198.	"	5770.	8
197.	"	6186.	9

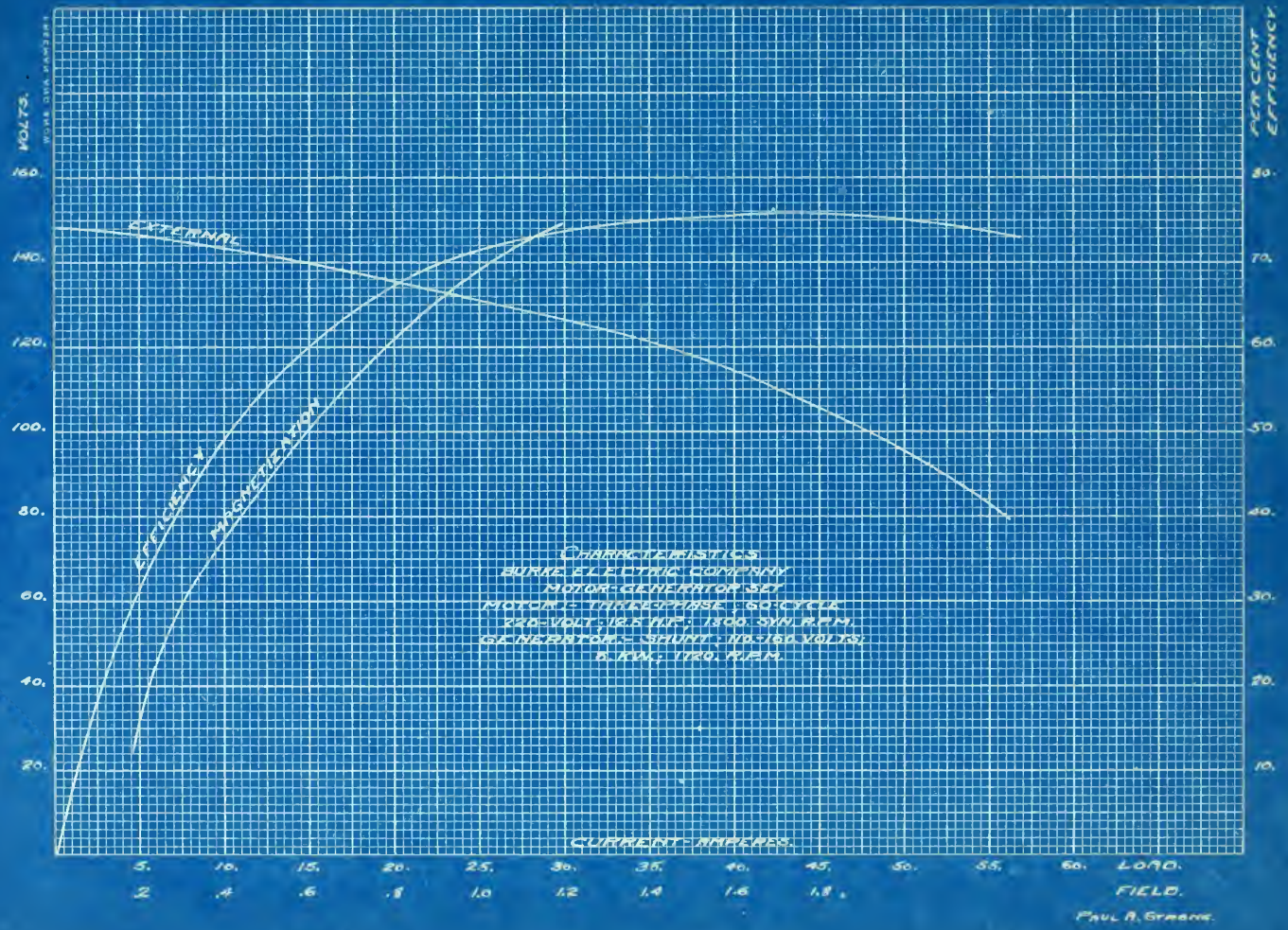
10. - 30.-volt set.

203.	60.75	550.	1
204.	"	560.	2
201.4	"	840.	3
203.	"	880.	4

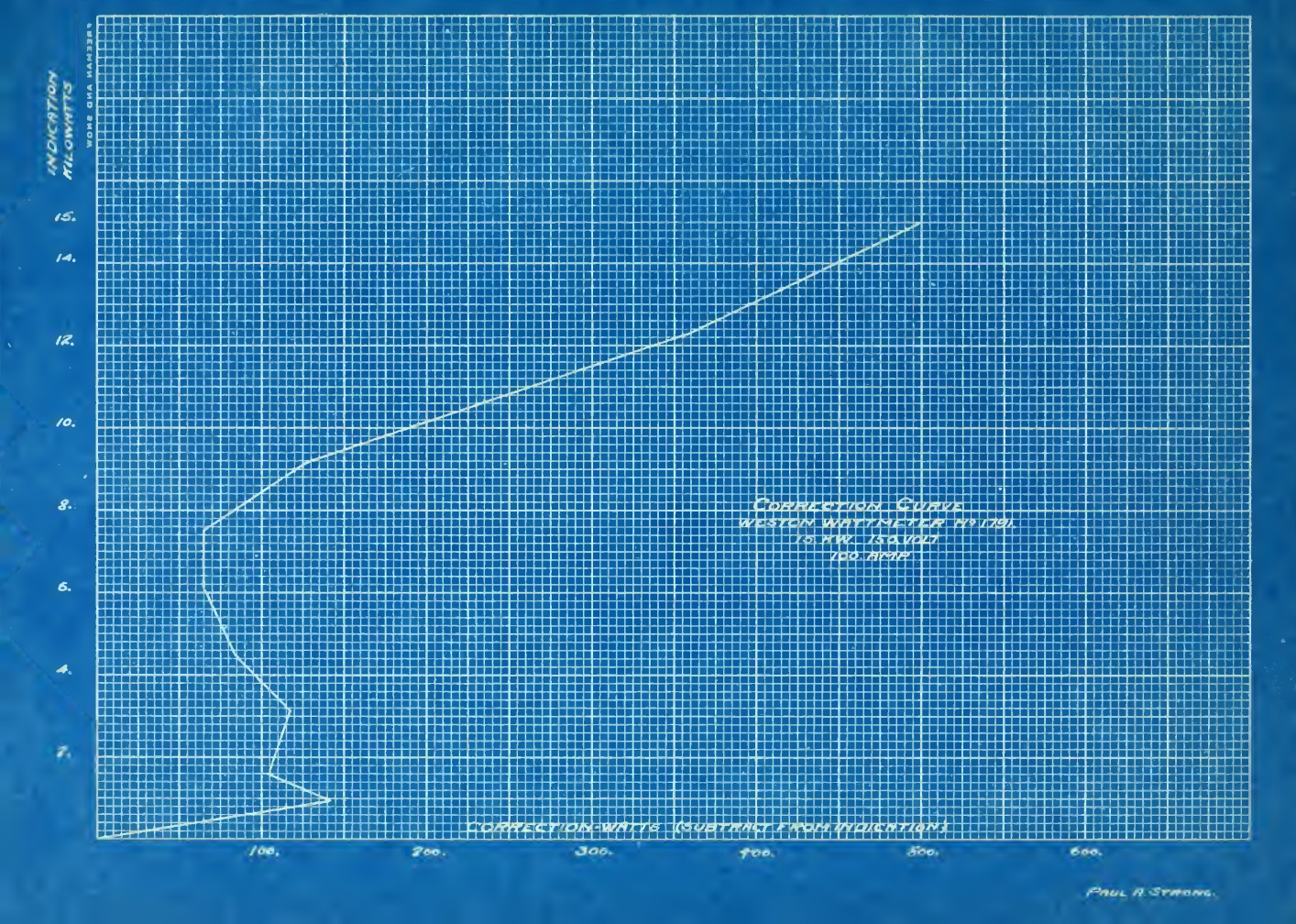
Load Characteristics (continued)

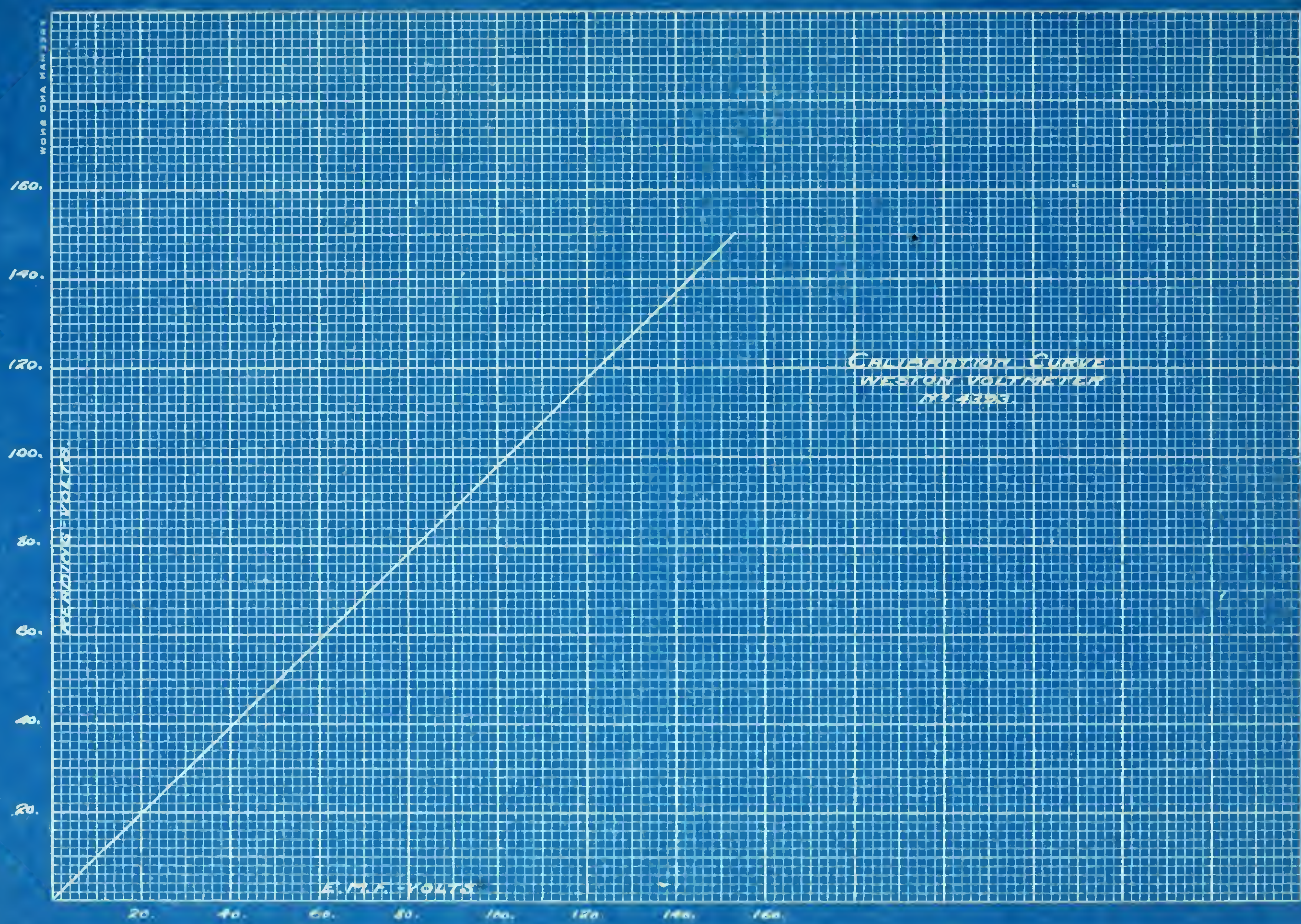
No.	** Voltage line	D.C. Current	Current field	** Speed armature
1	148.0	0.0	1.08	1830.
2	145.0	3.5	1.08	1817.
3	142.0	7.0	1.08	1785.
4	139.0	12.5	1.08	1785.
5	135.0	18.0	1.08	1785.
6	130.0	24.2	1.08	1763.
7	123.8	32.0	1.08	1744.
8	118.0	37.0	.88	1744.
9	111.0	42.0	.82	1744.
1	24.5	0.0	1.25	1744.
2	21.8	7.0	1.11	1735.
3	19.1	14.5	1.00	1725.
4	15.0	22.0	.82	1716.


CHARACTERISTICS
BOURNE ELECTRIC COMPANY
MOTOR-GENERATOR SET
MOTOR:- THREE-PHASE, 60-CYCLE;
220-VOLT, 25 AMP. 1800 SYN. R.P.M.
GENERATOR:- SHUNT; 70-30 VOLTS;
1.5 KW. 1720 R.P.M.
VOLTS.
PER CENT EFFICIENCY.
70.
60.
50.
40.
30.
20.
10.
EFFICIENCY
ARMATURE
CURRENT
CURRENT: AMPERES
5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60. 65. LOAD.
.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 FIELD.
PAUL A. STRONG.

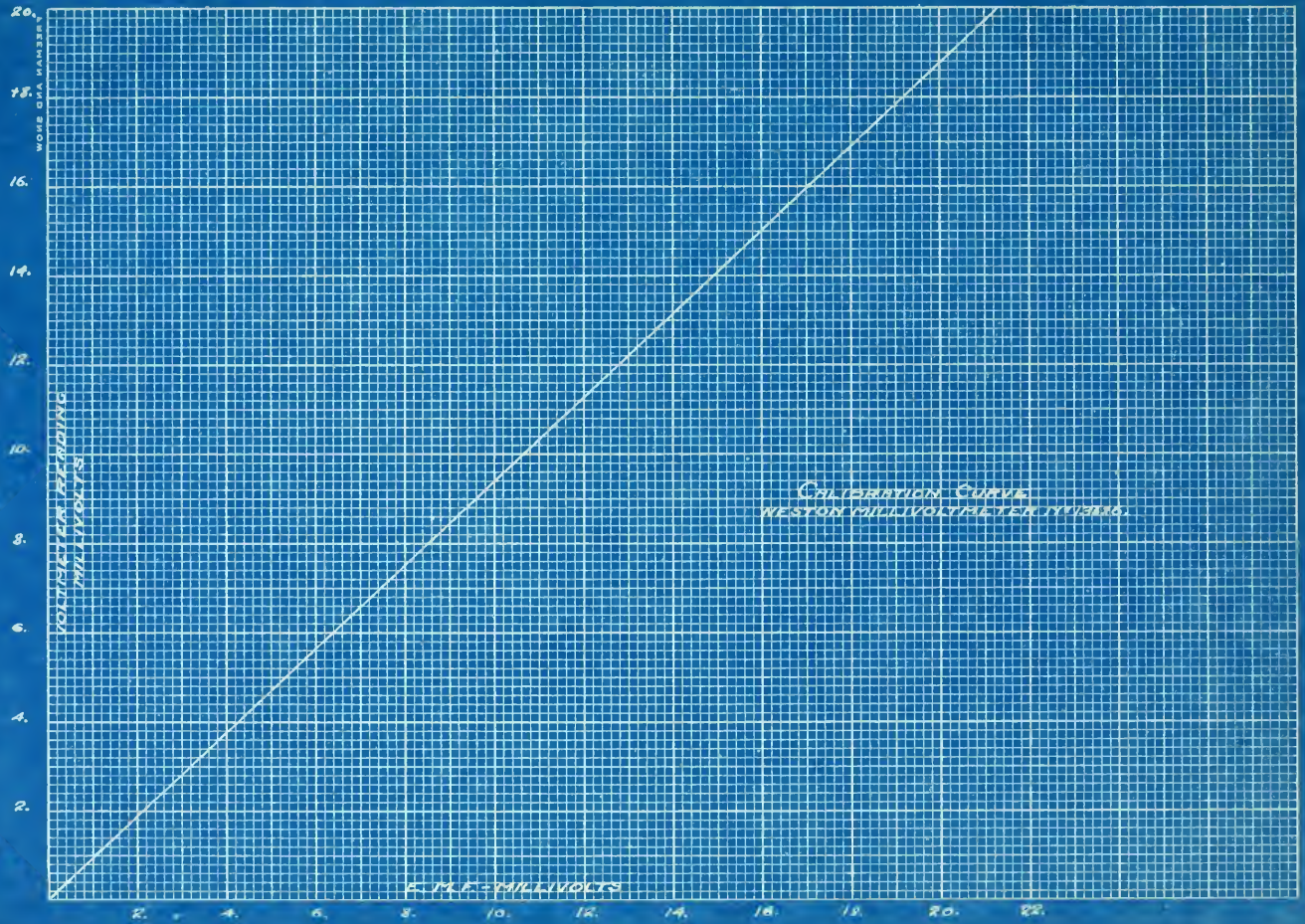


PAUL A. STRAUB.

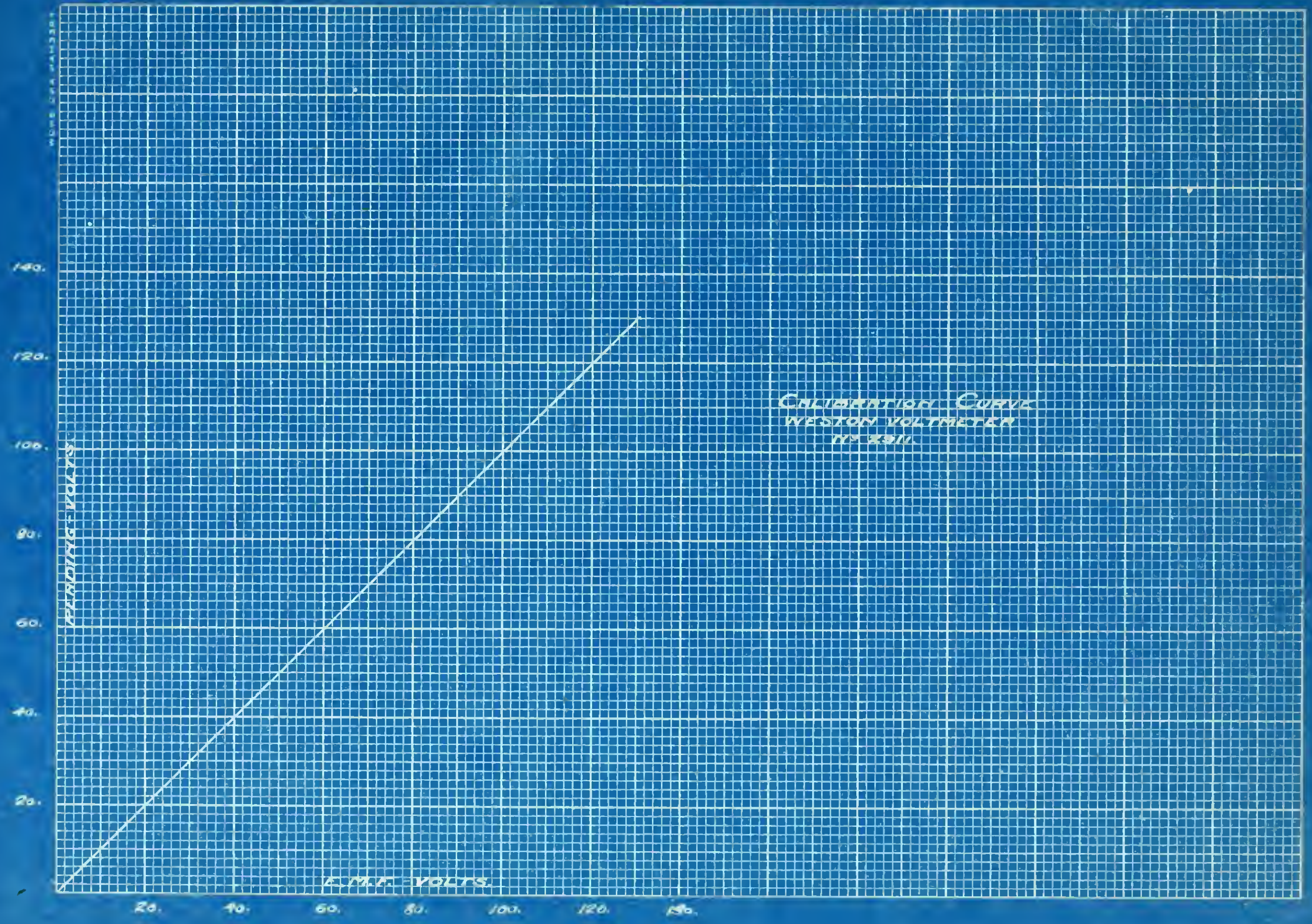

INDICATION KILOWATTS
WORK OF A WATTMETER
15.
14.
12.
10.
8.
6.
4.
2.
CORRECTION-WATTS (SUBTRACT FROM INDICATION)
100.
200.
300.
400.
500.
600.
CORRECTION CURVE
WESTON WATTMETER NO 1701
10 AMP. 150 VOLT
100 AMP
PAUL A. STRONG.



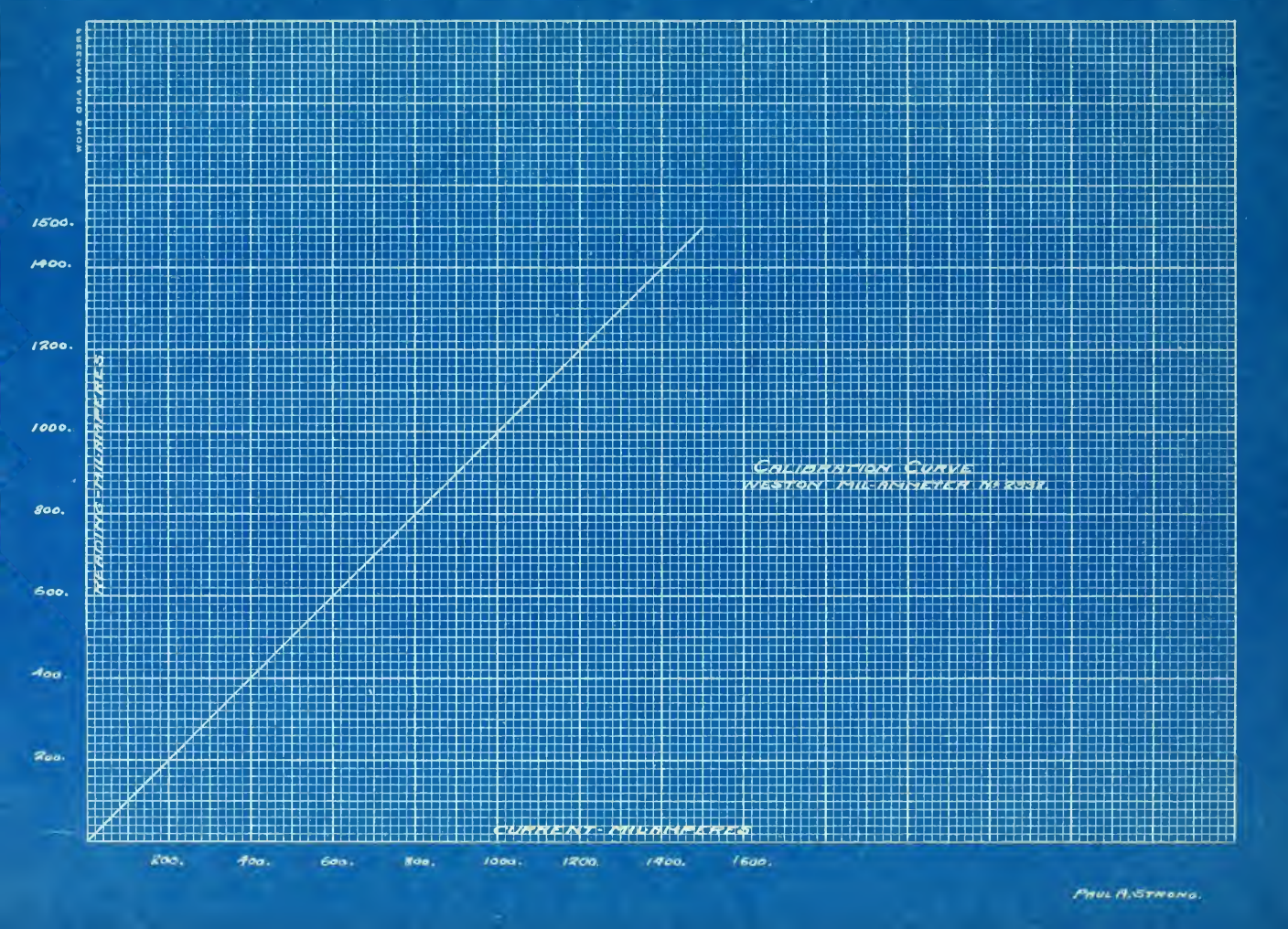
Paul A. Strong

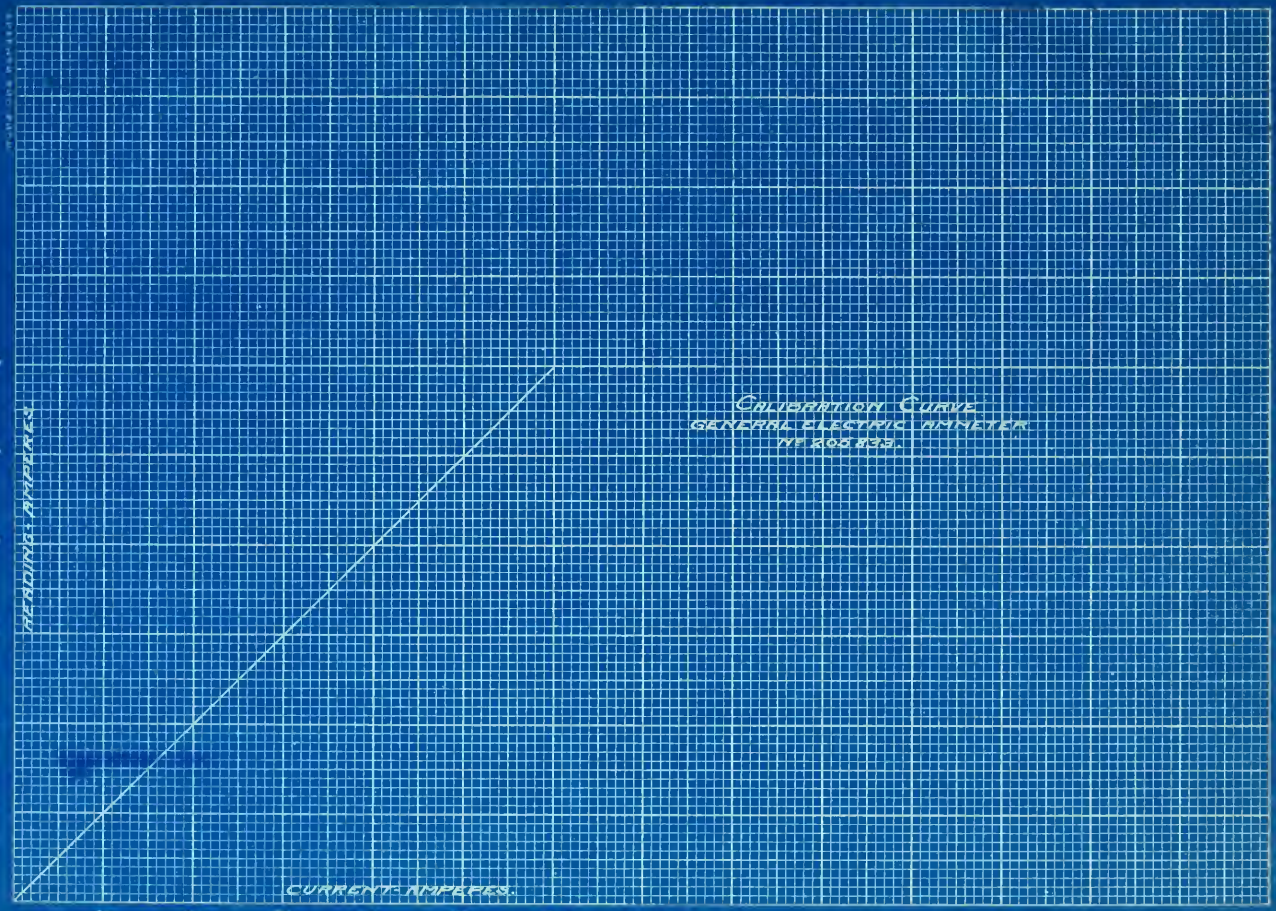


PAUL R. STRONG.



PAUL A. STRONG


1500.
1400.
1200.
1000.
800.
600.
400.
200.
DEFLECTION - MILLIMETERS
CURRENT - MILLIAMPERES
200.
400.
600.
800.
1000.
1200.
1400.
1600.
CALIBRATION CURVE
WESTON MILLIAMMETER No 2091.
PAUL A. STRONG.



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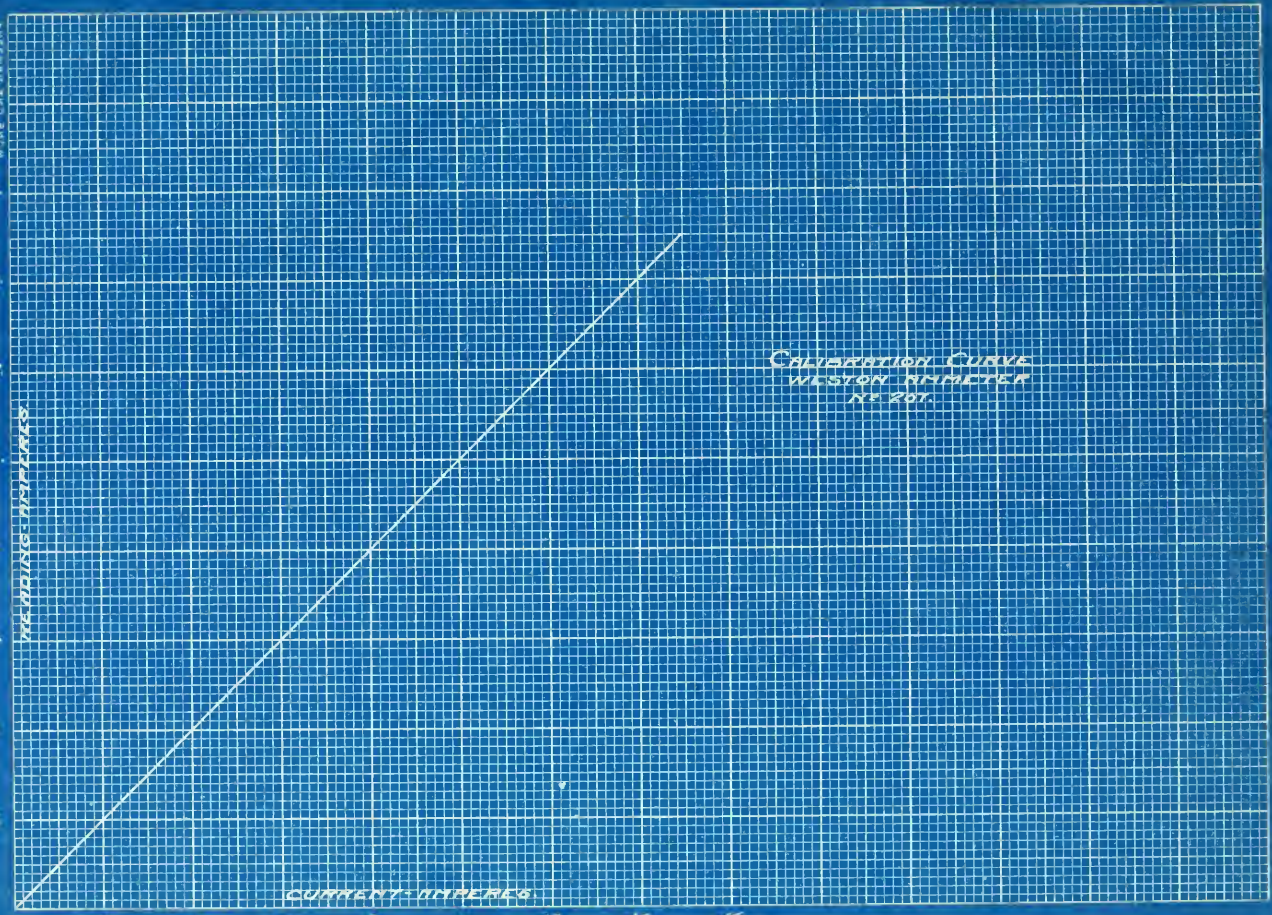

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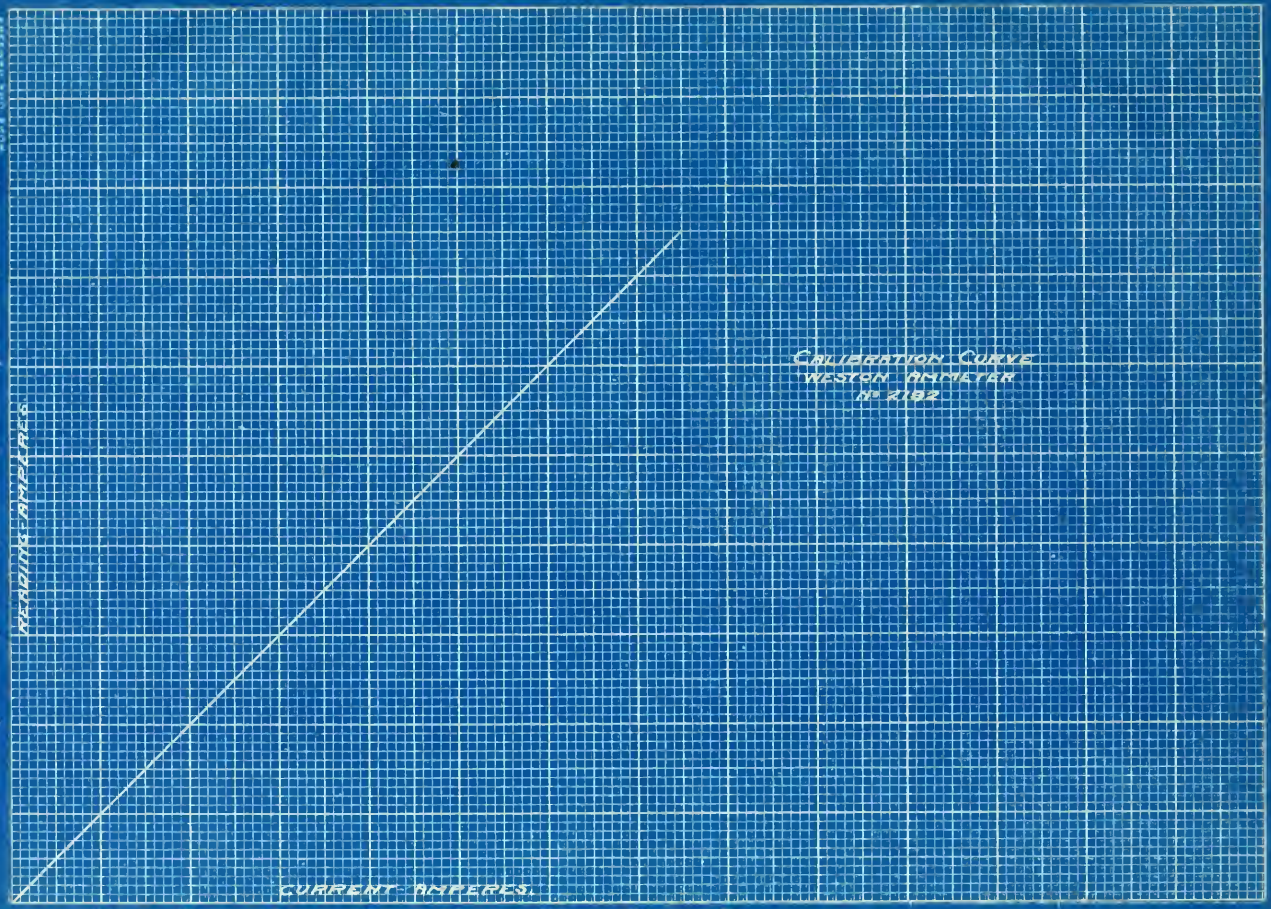

Paul A. Strong.